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DESULPHURISATION OF SHALE OILS,

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OIL-SHALE RESOURCES.

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NOTICES.

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Members of all classes are entitled to receive these publications free: for additional copies of the Journal they will be charged at the price of five shillings per part, and of the brochures at the prices stated on the wrappers, varying in proportion to bulk.

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Foreign weights, measures, and costs should be given whenever possible; and also their English equivalents.

It is suggested that authors append as complete a bibliography of the subject treated as may be possible.

All papers and notes submitted to the Institution are supposed to be original communications unless distinctly stated to be otherwise, in which case the exact reference to the previous publication should be given.

Communications upon papers read at meetings, notices of personal movements, or other matter for which publication is desired in the next issue of the Journal, should be in the hands of the Editor on or before the last day of January, March, May or November as the case may be. Subsequent delivery may be too late for insertion.

The Library. In the full catalogue of the Library, published in our brochure of September, were included the titles of such papers in journals received as bear upon any subject within the purview of the Institution. Such titles are not included in the intermediate lists given in our several parts, where, as below, the journals received are acknowledged in single entries.

The attention of such of our members as are authors is directed to the absence of their works from the Library, (with some exceptions), and we shall be particularly thankful for gifts of treatises on special branches of technology, and for separate copies of papers contributed to other Institutions and to journals, either in past or future.

The following six entries, by an unaccountable, but not less regrettable, accident, were omitted from the first part of the Library Catalogue in the recently issued Brochure of the Institution. They were duly referred to in the second section, under their respective subjects.

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—— Geology of the Country near Ngahlaingdwin, Minbu District, Burma. With Geological Map by C. Porro and R. Lewer, formerly Geologists to the British Burma Petroleum Co., and with footnotes and Appendix by G. de P. Cotter, Geological Survey of India. *Rec. Geol. Surv. Ind.*, vol. xlv, pp. 249–270, pls. xxv, xxvi. 1916.

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By Exchange.

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Dowling, D. B. The Southern Plains of Alberta. *Canada Geol. Surv. Mem.* no. 93, pp. 200; 35 pls., 3 maps. 1917.
(Natural Gas and Oil, pp. 120, 121.)

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FRANCE. MINISTÈRE DU COMMERCE, &c. SERVICES TECHNIQUES 5° Sect. Rapport Général sur les Ressources Nationales en Carburants. Pp. 88, 7 pls.; 61, 16 pls.; 68, 3 pls. 4to, *Paris*, 1917.

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GARFIAS, V. R., and H. J. HAWLEY. Funnel and Anticlinal Ring Structure associated with Igneous Intrusion in the Mexican Oilfields. *Bull. Amer. Inst. Min. Eng.*, 1917, pp. 1147–1159. (Exc.)

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HUBBARD, P. Laboratory Manual of Bituminous Materials for the Use of Students in Highway Engineering. Pp. xi, 153. 8vo, *New York and London*, 1916.

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——: its Origin, Progress and Purposes. Including its History, Library Catalogue and List of Members. Pp. 94. 8vo, *London*, 1917.

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By Exchange.

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—— Minutes of 4th Meeting, June 13, 1917.
From that Board.

Sinclair Magazine, nos. 1–3, 1917.
From the Sinclair Refining Co.

Society of Chemical Industry, Journal, vol. xxxvi, nos. 12–21. 1917.
By Exchange.

Spielmann, P. E. and G. C. Petrie. Some Observations on Crude Benzols. *Journ. Soc. Chem. Ind.*, vol. xxxvi, pp. 831–836. 1917. (& Exc.)
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By Exchange.

Exchange List.

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Mining Institute of Scotland.
North of England Institute of Mining and Mechanical Engineers.
North Staffordshire Institute of Mining and Mechanical Engineers.
Oil Age.
Oil and Colour Trades Journal.
Oil Exchange.
Royal Society of Arts.
Society of Chemical Industry.
South Staffordshire and Warwickshire Institute of Mining Engineers.
United States Geological Survey.
" " Patent Office.

The Journal is also forwarded to the British Museum, Copyright Department, to the Patent Office Library, to the University Libraries of Cambridge, Dublin, Edinburgh and Oxford, and to the National Library of Wales, Aberystwith.

Advertisements in the Journal. A limited number of Advertisements of firms interested in the Petroleum Industry, may be inserted in the Journal. Application for terms etc., should be made to the Secretary.

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PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that Members of the Institution send information regarding their movements to the Secretary for insertion under this heading.

At the early age of 54, inexorable fate removed, on October 24th, one of our valued members, Mr. George Thomas Holloway, long known as a metallurgist and assayer of pre-eminent capacity. He was born in Battersea on October 19th, 1863, and graduated at the Royal School of Mines, successively assisting Drs. Frankland and Thorpe as their Junior. In 1886 he commenced private practice in Chancery Lane, and a few years later established Testing Works in Limehouse. His active co-operation on the Councils and Committees of the Institute of Chemistry, the Institution of Mining and Metallurgy, the Society of Chemical Industry, the Society of Public Analysts, and other bodies, did not prevent his contributing extensively to technical literature, including the first editions of Redwood's Petroleum and Thorpe's Dictionary, besides acting as Examiner to the Board of Education and the Birmingham University, and as Juror in the Franco-British and Imperial International Exhibitions of 1908 and 1909. His crowning per-

formance was as Chairman of the Royal Ontario Nickel Commission, the exhaustive Report of which, issued in March 1917, is a monumental treatise on the subject, full of the most valuable information. His election as a member of this Institution was notified at the opening of the second session, October 19th, 1915.

Mr. J. A. Butlin has returned from Trinidad.

Dr. John Cadman, C.M.G., Professor of Mining, University of Birmingham, has received the Royal authority to wear the Cross of Officer of the Legion of Honour, which Decoration has been conferred upon him by the President of the French Republic, in recognition of valuable services rendered by him in the cause of the Allies.

Mr. W. Calder is a Second Lieutenant in the I.W. & D., R.E.

Mr. Stanley H. Chapman has been gazetted as being in the 51st Co., Chinese Labour Corps, att. Central Workshops, Tank Corps, B.E.F.

Mr. T. R. H. Garrett is a Lieutenant in No. 5 Squadron, R.N.A.S.

Mr. John E. Marshall Hall went to New Brunswick in August.

Mr. Alfred Harland has left Singapore, and is now stationed at Shanghai, China.

Dr. J. A. Leo Henderson has left for Canada.

Mr. D. L. Houghton, 2nd Lieutenant in the 5th Middlesex and R.F.C., is a Prisoner of War at Ströhen Camp, Hanover.

Mr. W. B. Hume is now in New Brunswick, having left Trinidad in October.

Mr. S. Lister James left for New Brunswick, Canada, in August.

Mr. B. F. N. Macrorie has returned to England from Persia.

Capt. T. S. Masterson returned from Rumania in August.

Mr. M. S. de Mendonça is a Lieutenant in the Port. H.A., and is at present stationed "somewhere in England."

Eng.-Captain M. Mizutani went to Japan, viâ America, in July.

Mr. F. W. Moon is now in Egypt, having arrived there from Singapore.

Mr. F. M. Penney returned from Russia in August.

Mr. T. P. Perrott returned to Maikop, South Russia, in August.

Mr. C. B. Rosenplaenter returned from Russia in September, and

Mr. G. J. Savage about the same time.

The Department of Scientific and Industrial Research.

The Committee of the Privy Council for Scientific and Industrial Research was appointed by Order in Council dated July 28th, 1915, to direct, subject to such conditions as the Treasury may from time to time prescribe, the application of any sums of money provided by Parliament for the organisation and development of scientific and industrial research. The Order in Council also appointed an Advisory Council, to assist the Committee of Council. By Charter dated November 23rd, 1916, the official members of the Committee of the Privy Council were created a Body Corporate under the name of "The Imperial Trust for the Encouragement of Scientific and Industrial Research" to hold and dispose of money and other property for the purposes of the Committee. On December 15th, 1916, a separate Department having its own Parliamentary vote was created for the service of the Committee.

Committee of the Privy Council.—The Lord President, The Secretary of State for the Colonies, The Chancellor of the Exchequer, The Secretary for Scotland, The Chief Secretary for Ireland, The President of the Board of Trade, The President of the Board of Education, The Most Hon. the Marquess of Crewe, K.G., LL.D., The Rt. Hon. Viscount Haldane of Cloan, K.T., O.M., The Rt. Hon. Lord Gainford of Headlam, The Rt. Hon. A. H. Dyke Acland, LL.D., The Rt. Hon. Arthur Henderson, M.P.

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Staff of the Department.—Secretary—Sir Frank Heath, K.C.B. Assistant Secretaries—Ll. S. Lloyd and P. C. Lyon, C.S.I. Technical Officers—A. S. Barnes, Dr. H. F. Coward, A. Richardson, and R. W. Stanners. Clerks, typists, etc.

EDITORIAL.

Native Hydrocarbons.

The legendary "untutored" savage, who inquired "how white man cook corn, so he can drink him out of bottle?", desired to apply the "firewater" to his own person. The modern quest is how to cook stone into a means of propulsion in transport, civil and military, and in projection of missiles against the over-tutored (and therefore more savage) occupants, *pro tem.*, of Central Europe.

The materials available for this purpose are extensive and accessible, lying in most cases at or near the surface, and patiently awaiting the attention of those who are overlooking their presence in eager search after more recondite matter. It is much more striking to put down a mile-deep boring than to dig a common pit, just as a bathe in the Jordan was beneath consideration by the dignified Syrian, as a substitute for dramatic display of Divine power over disease.

The writer has set forth, elsewhere in this number, what he holds to be irrefutable arguments against anticipating any appreciable supply of natural petroleum within the limits of the British Isles, but of solid sources of hydrocarbons in especial requirement there is enough and to spare. The drafters of the contemplated legislation, in grasping at imaginary petroleum, have ignored the abundant supply of material whence it can be formed by distillation, at a cost scarcely exceeding that of raising the raw mineral, and transporting the finished product. The main elements of the devolution, heat, time and pressure, being expressible in the terms of the first, may, in respect of cost, be ignored, as the material is itself a species of fuel, the supply of intelligent investigators and operators being the real *crux* of the problem.

In view of the infinite variety of Nature, there will continually be found differences in the material raised, involving corresponding modifications in some of the conditions of treatment, the adjustment calling for the closest possible approximation to uniformity throughout each portion of the plant, in order to ensure a definite product. Where such adjustment is not automatic, the more constant and intelligent must be the supervision of the operation. In this respect a standard legal maxim must be reversed, for he who acts through a less trained representative, risks inaction, or, it may be, detrimental procedure and disaster.

It is not the purpose of the present brief reference to deal in detail with the various sources of hydrocarbons available—cannel coal, lignite, shale and peat—in respect of the relative supply obtainable of each (practically unlimited in the last two cases), or of the degree in which success has attended the attempts at overcoming the practical difficulties of manipulation. Besides the desired modifications of the natural hydrocarbons, which is becoming more and more thoroughly comprehended as errors in prior operations are recognised and abandoned, the chief problems remaining for solution may be included under three heads, connected respectively with compounds of sulphur and of nitrogen, and with the moisture in the raw material. The definite aim here should be not merely the elimination, at minimum cost, of matters undesirable in the finished product, but if possible their collateral conversion into other and useful by-products. These independent desiderata, elimination and conversion, will probably be eventually found mutually compatible, and no solution of either problem will be ultimately satisfactory that does not at the same time solve the other, whether by truly simultaneous processes, or by leaving the separated compounds, sulphurous, nitrogenous and hydrocarbon, in a condition capable of useful modification by subsequent treatment.

Finality in chemical knowledge, or in the technique of its application, is presumably as inaccessible as perfection in any other department, but those who may be inclined to be discouraged by the distance of the desired goal may take heart by contemplation of the continuous advance made in every direction in which man has attempted to bring the forces of Nature under control. Almost daily we hear of the mastery of some difficulty previously pronounced insuperable by the faint-hearted. And not seldom the victory is due to the suggestion of, or actually achieved by, some one outside the circle of specialists, some one who "didn't know it was impossible, so went and did it." The old fable of mouse and lion has often been verified in the history of invention.

Sir Dugald Clerk, in the first of the Trueman Wood Lectures, recently delivered, has shown the inter-relation of academic investigation and practical working, each alternately taking the lead, in several branches of technological development. Probably the proverbial repetition will occur in the history of that part of the art of distillation which is miscalled destructive, and the source of improvements will oscillate between laboratory and bench.

The Chimæra.

How and when the word chimæra acquired its modern meaning of a visionary prospect may be known to students of archaic language. The original name was applied to an issue of natural gas at Janartasch, on the coast of the Gulf of Adalia, in the Province of Lycia, Asia Minor. This gas, artificially led to an altar, probably piled with stones of nature akin to asbestos, produced a perennial fire, whence appropriate donations to the presiding priest could secure brands for domestic use. Thence, probably by an overpowering outburst of the gas, arose the legend of a mighty monster concealed within the rocks, and issuing at intervals to seize his prey. On the other hand, the figment may have been a priestly design to prevent illicit approach to the altar by persons not duly qualified, whether impecunious or inquisitive.

The derivation of the name from the Phœnician word *chamirah* (burning) is again a matter of philological research. Probably a realisation of the fictitious character of the monster led to the application of the term to schemes of similar magnitude, and as voracious (of capital), but equally unsubstantial.

The discharge is not pure methane, as a perceptible odour of "naphtha or iodine" is recorded by one observer, whilst the soot deposited by the flame is said to be used as a pigment, as a remedy in ophthalmia and for other purposes. The medical application suggests the antiseptic action of some undestroyed hydrocarbon, condensed in the soot of decomposed gas imperfectly supplied with air.

The emanation appears to be evolved from masses of serpentine in course of modification by internal or external action. The asbestos-like rock suggested above, would be a natural concomitant of the serpentine. The mode of occurrence of the latter is by intrusion through the Eocene rocks of the vicinity, but these are presumably underlaid by those of the Cretaceous system, which is charged with various forms of hydrocarbon throughout Syria, from the Dead Sea to Lebanon and farther northward.

The formation of petroleum appears to have been especially active in the Levant region from the Cretaceous epoch to the present era, and whilst most of the product has doubtless been dissipated in the course of ages, there are probably large stores still extant and easily accessible. It is not chimerical, in the modern sense of the word, to anticipate that the resuscitation of Jerusalem may be effected by the same agency as the ancient destruction of Sodom, the difference lying in control of the flow of oil.

Twenty-Fourth General Meeting.

The first meeting of the Session 1917–1918 of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2, on Tuesday evening, 16th October, 1917, Mr. Charles Greenway (President) occupying the Chair.

The Members of Council present were Profs. Brame and Cadman, Messrs. Andrew Campbell, Arthur W. Eastlake and T. C. Palmer, Dr. F. M. Perkin and Sir Boverton Redwood, Bart.

The Hon. Secretary reported that the following gentlemen had been elected :—

As *Member of Council*:—Prof. J. S. S. Brame.

As *Members* :—Eugene Coste, Thomas Dewhurst (transference from Associate Member to Member), Harry Mejor, Herbert Victor Mitchell, Mitsutaro Mizutani, Alfred William Rogers, Francis Stafford Smith and Arthur Beeby Thompson.

As *Associate Members* :—Charles Ford Bird (transference from Associate to Associate Member), Tom Rutherford Cruwys, Wilfred Emil Guttentag (transference from Student to Associate Member), Terence Shields Harrington, Peter Stewart Hay and Herbert Wray Hole.

As *Students* :—Desmond L. Kirkpatrick and Manmatha Kumar Ray.

Before calling on Mr. Lomax to read his paper on "The Testing and Standardisation of Motor Fuel," the President read the following letter from **Mr. A. Duckham** :—

Mr. Lomax's paper serves a very useful purpose in summarising in one published document so many examples of divergence in figures, resulting from the various methods of testing which are in vogue. It has, however, suggested to me an idea which I venture to think might have the consideration of the Council of the Institution, and which, I think, if acted upon, would result in considerable advantage to the consulting chemist, refiner and merchant, indeed to all those who are interested in the testing of petroleum products, and at the same time be a credit to our Institution, tending towards its recognition as *the* authority on petroleum matters. My suggestion is that the Institution should appoint a Standardisation Committee whose reference should be to investigate methods of testing and to recommend standards for adoption in this country. At present, in even the simplest tests, carried out on well-standardised apparatus, there will be found variations in results in the hands of different

operators, this being due, of course, to small differences in manipulation, which have not been sufficiently detailed in the published instructions as to conduct of the tests.

Mr. Lomax has specially instanced the case of distillation. I would draw your attention to such minor tests as melting-points, boiling-points, viscosities, both on account of differences in manipulation and of radical differences in the method adopted. Then, again, there are different methods of expressing results; for example, some laboratories will express their viscosity figures on a Redwood instrument in terms of the comparison with rape oil, whilst others give it in the number of seconds. Certain laboratories will report viscosities at 70° F., 140° F. and 200° F., others favouring 60° F., 100° F. and 212° F., and many other variations in these figures. In the determination of the cold test, of the asphaltic content, of the liability to emulsification, and in the estimation of aromatics, and so on, it is seldom found that the methods of any two laboratories are strictly comparable. I feel that in this short letter I have dealt very inadequately with this most important subject, but I trust that what I have written will show what is in my mind, and that it may be considered of sufficient importance for the Council to decide to take action in the direction I venture to suggest. If such action were taken, I think it would be found advisable that the members of the Committee should be representative, not only of the consulting chemist, but also of the Works chemist.

Yours sincerely,

ALEX. DUCKHAM.

The President, commenting on the foregoing letter, said he was sure all would agree with Mr. Duckham. It did not greatly matter what method of testing was adopted so long as the result shown was correct. What was wanted was uniformity of system, understood alike by producer and user—something equivalent to a universal decimal system. The question was one which should be taken up and settled at an early date, more particularly as there was now a disposition on the part of the many countries with whom we were working against German domination, to adopt a closer relationship and find a common basis in all commercial matters.

Mr. Lomax then read the following paper, exhibiting the apparatus described :—

Testing and Standardisation of Motor Fuel.

By E. Lawson Lomax, M.Sc., F.C.S., *Member*.

In bringing forward this paper to-night, I am afraid I run the risk of being asked: What is the use of tests for motor-spirit, when we have no spirit to test? Well, this may be so from a private point of view, at the present time; but the day will come, and we all hope very soon, when we shall be revelling in the old-time abundance of this most important petroleum product. Seeing that our future consumption of motor-spirit will in peace-time be no less than two or three hundred million gallons per annum, and be of many million pounds in value, it appears that sufficient attention has not in the past been paid to its testing and standardisation. Before, however, passing on to the actual testing of petroleum-spirit, I will briefly review the various classes of hydrocarbons which we may expect to be present in the spirits from various sources, and which are a reflex of the complex character of this, probably, the simplest of all petroleum products.

These classes are the paraffins, *iso*-paraffins, *cyclo*-paraffins and aromatic hydrocarbons, many of the members in each class having been isolated from various petroleum spirits. Some of the individual members are mentioned in the following tables, the figures quoted in which are mainly taken from Richter's Lexicon and Beilstein, and as such will, I think, be accepted as fairly correct.

A glance at tables I–IV will show that, speaking generally, the specific gravities of the paraffins and *iso*-paraffins, with approximately the same boiling-points, are lower than those of the *cyclo*-paraffins; which in turn are lower than those of the aromatic hydrocarbons. It is thus conceivable, that with the same range of boiling-points, in other words the same degree of volatility, motor-spirit may vary very widely in its specific gravity, and therefore the specific gravity of a motor-spirit is no definite criterion of its value as a fuel, and only serves as the basis for calculating the weight per given volume. It is surprising, however, in these days how often one hears

Table I.

Paraffins (Normal).

	Formula.	Specific Gravity.	Boiling-point.
Butane ...	C_4H_{10}	$D_0 = 0{\cdot}600$	gas.
Pentane ...	C_5H_{12}	$D_{14} = 0{\cdot}627$	38° C.
Hexane ...	C_6H_{14}	$D_{20} = 0{\cdot}658$	69° C.
Heptane ...	C_7H_{16}	$D_{20} = 0{\cdot}683$	98·5° C.
Octane ...	C_8H_{18}	$D_{20} = 0{\cdot}702$	125·5° C.
Nonane ...	C_9H_{20}	$D_{20} = 0{\cdot}718$	149·5° C.
Decane ...	$C_{10}H_{22}$	$D_{20} = 0{\cdot}730$	173° C.

TABLE II.

Iso-PARAFFINS.

	Formula.	Specific Gravity.	Boiling-point.
Dimethyl ethyl methane	$CH_3\,CH_2\,CH(CH_3)_2$	$D_0 = 0.6387$	30° C.
Tetramethyl methane	$C(CH_3)_4$		Gas.
Methyl diethyl methane	$CH_3\,(C_2H_5)_2\,CH$	$D\frac{20\cdot5}{4} = 0.6765$	64° C.
Dimethyl propyl methane	$CH_3\,CH_2\,CH_2\,CH(CH_3)_2$	$D_0 = 0.7011$	62° C.
Di-*iso*propyl	$(CH_3)_2\,CH\,CH(CH_3)_2$	$D_{17.5} = 0.668$	58° C.
Trimethyl ethyl methane	$CH_3\,CH_2\,C(CH_3)_3$	$D_{20} = 0.6488$	49·6° C.
β Methyl hexane (*iso*heptane) ...	$(CH_3)_2\,CH{\cdot}CH_2\,CH_2\,CH_2\,CH_3$	$D\frac{0}{4} = 0.7067$	89·9–90·4° C.
3 Methyl hexane	$CH_3{\cdot}CH{\cdot}C_2H_5\,CH_2\,CH_2\,CH_3$	$D_{17} = 0.7806$	80–88° C.
Triethyl methane	$CH(C_2H_5)_3$	$D_{27} = 0.689$	95–98° C.
Diethyl dimethyl methane	$CH_3 > C < C_2H_5$ (with CH_3 and C_2H_5)	$D_0 = 0.711$	86–87° C.
Di-*iso*butyl (2·5 dimethyl hexane) ...	$(CH_3)_2\,CH\,CH_2\,CH_2\,CH(CH_3)_2$	$D_0 = 0.7111$	108·5° C.
2·5 Dimethyl heptane	$(CH_3)_2\,CH\,CH_2\,CH_2\,CH(CH_3)\,C_2H_5$	$D_{16.5} = 0.8813$	128–134° C.
Di-propyl ethyl methane	$CH_3\,CH_2\,CH_2 > CH < CH_2\,CH_3$ (with $CH_3\,CH_2\,CH_2$)	$D_{20} = 0.7407$	138–139° C.

TABLE III.

NAPHTHENES OR CYCLO-PARAFFINS.

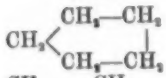
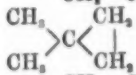
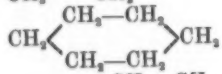
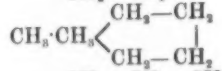
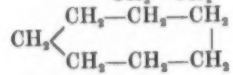
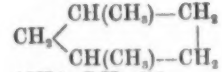
	Formula.	Specific Gravity.	Boiling-point.
Pentamethylene (*cyclo*-pentane)		$D_{20.5}$ = 0·7506	50·2—50·8° C.
1·1 Dimethyl trimethylene (1·1 dimethyl *cyclo*-propane)		D_{20} = 0·6604	21° C.
Hexahydro-benzene (*cyclo*-hexane)		D_0 = 0·7478	79° C.
Methyl penta-methylene (methyl *cyclo*-pentane)		D_{21} = 0·7501	71—72° C.
Suberane (*cyclo*-heptane)		D_{20} = 0·8094	117 –117·5° C. 743 mm.
Hexahydro-toluene (methyl *cyclo*-hexane)	$CH_3(C_6H_{11})$	D_0 = 0·7741	94—96° C.
1·3 Dimethyl *cyclo*-pentane		D_{20} = 0·7543	93° C.
Octonaphthene (hexahydro *m*-xylol)	$(CH_3)_2\ C_6H_{10}$ 1·3	D_{20} = 0·765	116—118° C.
Iso-octonaphthene	$(CH_3)_2\ C_6H_{10}$	$D_{17.5}$ = 0·7637	122·3° C.
Nononaphthene (hexahydro-cumol)	$(CH_3)_3\ C_6H_9$ 1·3·4	D_{20} = 0·7667	135—136° C.

TABLE IV.

AROMATIC HYDROCARBONS.

	Formula.	Specific Gravity.	Boiling-pt.
Benzene	C_6H_6	D_0 = ·899 D_{20} = ·8799	80·4° C.
Toluene	$C_6H_5CH_3$	D^{15}_{4} = ·8708	110·3° C.
o-Xylene	$(CH_3)_2C_6H_4$ 1·2	D_0 = ·8932	142° C.
m „	$(CH_3)_2C_6H_4$ 1·3	D_0 = ·8812	139° C.
p „	$(CH_3)_2C_6H_4$ 1·4	D_0 = ·8801	138° C.
Ethyl benzene ...	$C_2H_5C_6H_5$	D_0 = ·8832	134° C.
Mesitylene	$(CH_3)_3C_6H_3$ 1·3·5	D^{15}_{4} = ·8694	164·5° C.
n-Propyl benzene ...	$C_6H_5CH_2CH_2CH_3$	D_0 = ·8810	158·5° C.
Iso-propyl benzene (cumene)	$C_6H_5CH(CH_3)_2$	D_0 = ·8798	153° C.

the question: What is its specific gravity?, when discussing the question of motor fuel with the motor engineers or even the commercial oil-man; and I think it is high time that this point of specific gravity should be altogether shelved, and replaced by that of volatility: the "man in the street" would then be better able to judge of the quality of spirit he was buying than he has been able to do in the past.

In addition to the four classes of hydrocarbons above mentioned, members of the olefine series have been found in petroleum from North America; Markownikow and Ogloblin (*J. Russk. Ph.-Kh. Obsch.*, xiii, 179, 1881; xv, 237, 1883) found small quantities of acetylene hydrocarbons in oil from Baku; while Boussingault (*Ann. Chim. Phys.*, lxi, 141, 1837; and lxxiii, 443, 1840) reported camphenes of the formula C_nH_{2n-4} in the distillate from the asphalt of Pechelbronn. These latter hydrocarbons, however, occur in only very small percentages in any petroleums, and in the case of olefines and acetylenes would be removed in the acid wash, and so would not be present in the finished motor-spirit.

Other bodies present in motor-spirits as impurities are sulphur-compounds of the various hydrocarbons, which are many and complex, the elimination of these being one of the great problems of oil refiners and chemists. It is fortunate for the peace of mind of most chemists that the question of the separation of the aforementioned compounds is not necessary when testing and valuing motor-spirits, a few comparatively simple tests giving us the required information. Of these tests, the most commonly applied are those of specific gravity, range of distillation, and sulphur-content, apart from observations as to colour and smell.

Specific gravity.—Methods of ascertaining the specific gravity of fluids are so well known that it is unnecessary for me to enlarge on them here, being embodied in most text-books on oils. Two general methods are employed, i.e. direct weighing, by means of the specific gravity bottle or by pyknometer, and by displacement, using the Westphal balance or hydrometer.

With regard to the specific gravity determination, I would, however, like to point out one source of confusion. In the petroleum industry, the accepted standard temperature for determining the specific gravity is 15·5° C. or 60° F., and all values are or should be calculated to this standard. It would be well if a definite standard could be agreed on by all chemists, for in looking through investigations carried out by various workers, it will be seen that specific gravities are determined at many different temperatures, thus leading to great confusion.

Distillation tests.—The determinations of the boiling-points or degree of volatility of motor fuels have in the past been carried out by one of two methods: (1) That of our Past-President, Sir Boverton Redwood; (2) a modification of the Engler method for the valuation of crude petroleum.

The distillation method of Sir Boverton Redwood is fully described in his work on Petroleum and its Products, Edition 3, vol. ii, p. 207, and it is not necessary for me to enter into these details. Engler's method is also described in the same volume, p. 204. The difference between these two tests is that the first is a continuous distillation from start to finish, whereas in the second test the distillation is interrupted at certain specified temperatures.

The instructions for the original Engler test are:—"As soon as the requisite temperature (150° C. for the first fraction) is attained, the lamp is withdrawn until the temperature has fallen at least 20°, when the oil is re-heated to the boiling-point, and again cooled, this process being repeated until no more distillate is obtained." These instructions are interpreted in various ways by different investigators, some of whom say that any particular fraction is complete, if the temperature as indicated by the thermometer rises above the mark, even after the flame is removed, while others maintain that so long as any distillate is obtained in re-heating the oil to the desired temperature, the test should be continued.

Table V shows the effect of these different methods of carrying out the test, on two samples of benzine, sample A being the original one, and sample B being a mixture of sample A with about 5 % of a light petrol. Against these are placed the figures obtained by Redwood's method of distillation.

Table V.

Comparison of Redwood and Engler Methods of Distillation.

1. Redwood method.
2. Engler method, end of fraction being when thermometer rises above temperature after removal of flame.
3. Engler method, heatings continued so long as any distillate comes over, below temperature of fraction.

Average results of three distillations by each method.

	Spirit A.			Spirit B.		
	1	2	3	1	2	3
Specific gravity at 15·5° C...	·764	·764	·764	·762	·762	·762
Initial boiling-point	72° C.	69° C.	68° C.	74° C.	65° C.	63° C.
Volatile below 100° C. ..	4·9%	11·5%	19·0%	7·9%	16·4%	25·2%
,, ,, 125° C. ..	59·8%	64·6%	69·9%	61·2%	66·7%	71·9%
,, ,, 150° C. ..	89·8%	90·5%	92·6%	90·5%	92·7%	93·4%
Total distillate	98·6%	96·2%	97·1%	98·7%	97·5%	97·4%
Residue in flask	1·1%	1·2%	1·6%	1·1%	1·0%	1·3%
Loss	0·3%	2·6%	1·3%	0·2%	1·5%	1·3%
Final boiling-point	176° C.	175° C.	175° C.	176° C.	174° C.	173° C.
Barometric pressure.. ..	29·95″	30·1″	29·8″	30·1″	29·9″	29·9″
Average time occupied in making test (in minutes)..	50	90	190	55	90	190

It will be noticed that the Engler method 2 clearly indicates the addition of low-boiling products, which is emphasised by method 3, and is not so obvious in the Redwood method.

The time taken up by method 2 is much longer than by the Redwood method, while by method 3 it is almost four times as long. Again, the liability to personal error is much greater by the Engler method than by the Redwood, great care being required, even by skilled manipulators, to obtain concordant results on the same sample of spirit, while independent operators may obtain results varying within comparatively wide limits.

On the other hand, the Redwood method, while giving concordant results in the hands of independent investigators, is very easy of manipulation, especially if the rate of fall of the drops from the end of the condenser is timed to the beat of a calibrated metronome, so as to give the required speed of distillation, i.e. 2·5 cc. per minute. In the instructions given, the distillation is to be carried out over a sand-bath, but this is not absolutely essential, as practically identical results are obtained, whether the distillation is carried out over a naked flame, over a flame protected by a plain gauze, over a flame protected by an asbestos centre gauze, or over a sand-bath as specified. This is shown clearly in table VI, which gives the average results of tests by the above-mentioned methods on various samples of spirits.

TABLE VI.

COMPARISON OF METHODS OF CARRYING OUT REDWOOD DISTILLATION TEST.

1. Unprotected flame impinging direct on flask.
2. Flame protected by plain iron gauze.
3. Flame protected by asbestos centre gauze.
4. Flame protected by sand bath.

All tests carried out on samples from one batch of spirit.

	Experimental Spirit.				Red Line Spirit.				Mex No. 1.			
	1	2	3	4	1	2	3	4	1	2	3	4
Specific gravity at 15·5° C.	·722	·722	·722	·722	·749	·749	·749	·749	—	·714	—	·714
Initial boiling-point	46° C.	46° C.	47·5° C.	45° C.	58° C.	59° C.	60° C.	64° C.	—	44° C.	—	42° C.
Volatile below 100° C.	41·5%	40·5%	41·0%	41·0%	20·0%	21·0%	20·0%	20·0%	—	40·0%	—	40·0%
,, ,, 125° C.	73·0%	72·5%	73·0%	72·0%	66·0%	65·5%	65·0%	65·5%	—	71·0%	—	71·0%
,, ,, 150° C.	91·0%	91·0%	91·0%	91·0%	90·0%	90·0%	89·0%	89·5%	—	89·5%	—	90·0%
Total distillates	96·0%	96·5%	96·5%	97·0%	98·0%	98·0%	97·5%	98·0%	—	96·0%	—	96·5%
Residue in flask	2·0%	2·0%	1·5%	1·5%	1·5%	1·5%	1·5%	1·25%	—	2·0%	—	2·0%
Loss	2·0%	1·5%	2·0%	1·5%	0·5%	0·5%	1·0%	0·75%	—	2·0%	—	1·5%
Final boiling-point	175° C.	174·5° C.	176° C.	175° C.	180° C.	182° C.	181° C.	182·5° C.	—	>200° C.	—	>200° C.
Barometric pressure	29·9"	30·1"	30 0"	29·9"	30·4"	30·4"	30·4"	30·2"	—	30·2"	—	30·25"

	Pratt No. 2.				Shell No. 2.			
	1	2	3	4	1	2	3	4
Specific gravity at 15·5° C.	·739	·739	·739	·739	·745	·745	·745	·745
Initial boiling-point	55° C.	54° C.	56° C.	51° C.	65° C.	64° C.	65° C.	65·5° C.
Volatile below 100° C.	25·0%	24·5%	24·5%	26·0%	17·0%	17·5%	16·5%	16 0%
,, ,, 125° C.	65·0%	64·5%	64·5%	65·0%	56·0%	56·5%	57·0%	57·0%
,, ,, 150° C.	89·0%	88·0%	88·0%	89·0%	87·5%	87·5%	87·0%	87·5%
Total distillate	97·0%	96·5%	97·0%	97·5%	97·5%	97·5%	97·5%	98·5%
Residue in flask	1·5%	1·5%	1·5%	1·5%	1·5%	1·5%	1·5%	1·0%
Loss	1·5%	2·0%	1·5%	1·0%	1·0%	1·0%	1·0%	0·5%
Final boiling-point	178° C.	179° C.	179° C.	177° C.	182° C.	181° C.	183° C.	182° C.
Barometric pressure	30·4"	30·4"	30·4"	30 2"	30·3"	30·3"	30·3"	30·3"

A glance at this table will show that the figures obtained by the modified methods on the various spirits agree amongst themselves well within the limits of experimental error. This test, however, has one disadvantage, in that it tends to mask the presence of low-boiling hydrocarbons, particularly when they are present in small quantities.

I have carried out a small series of experiments with practically pure hydrocarbons and mixtures thereof to show this masking action, which are tabulated below:

TABLE VII.

COMPARISON OF BOILING-POINTS OF PURE HYDROCARBONS AND MIXTURES THEREOF. DISTILLATIONS CARRIED OUT BY REDWOOD'S METHOD OVER PLAIN GAUZE.

	Benzene. Sp.gr. ·8825.	Toluene. Sp.gr. ·868.	Xylenes Sp.gr. ·861.	Benzene 1 pt. Toluene 1 pt. Xylenes 1 pt.	Benzene 1 pt. Toluene 1 pt. Xylenes 2 pts.
Initial boiling-point ..	78·5° C.	109° C.	135·7° C.	90·5° C.	95·5° C.
10 % volatile below ..	80·1° C.	109·9° C.	137·2° C.	99·5° C.	105·8° C.
20 % " " ..	80·2° C.	110·0° C.	137·5° C.	102·0° C.	108·8° C.
30 % " " ..	80·2° C.	110·0° C.	137·7° C.	104·3° C.	112·5° C.
40 % " " ..	80·3° C.	110·1° C.	137·8° C.	108·2° C.	117·8° C.
50 % " " ..	80·4° C.	110·2° C.	138·0° C.	112·5° C.	123·2° C.
60 % " " ..	80·4° C.	110·2° C.	138·0° C.	118·2° C.	127·6° C.
70 % " " ..	80·5° C.	110·3° C.	138·2° C.	124·0° C.	131·8° C.
80 % " " ..	80·7° C.	110·3° C.	138·3° C.	129·5° C.	134·9° C.
90 % " " ..	81·0° C.	110·4° C.	138·5° C.	135·0° C.	137·7° C.
95 % " " ..	81·5° C.	110·7° C.	138·7° C.	137·8° C.	138·6° C.
Total distillate ..	98·5 %	98·0 %	98·5 %	98·0 %	98·0 %
Residue in flask ..	1·0 %	1·0 %	1·0 %	1·5 %	1·0 %
Loss	0·5 %	1·0 %	0·5 %	0·5 %	1·0 %
Final boiling-point ..	86° C.	111·6° C.	139·4° C.	138·8° C.	139·2° C.
Barometric pressure ..	30·1"	30·1"	30·1"	30·3"	30·3"

The benzene, toluene, and xylenes used were coal-tar products, and were sufficiently pure for the purpose, as shown by their boiling-points. Two mixtures were made of these compounds in varying proportions: in the case of the mixture of equal portions it will be seen that the initial boiling-point is 12° C. higher than that of the benzene used, while in the other it is 18° C. higher, and in both cases the initial b.-p. for the mixture is higher than the final b.-p. of the benzene present. The average buyer of such a mixture on the above test might well be excused for stating that there was no body present having such a low boiling-point as benzene.

W. Trotman (*J. Soc. Chem. Ind.*, 1906, 1202), in a paper on the selection of benzine for degreasing, pointed out this masking effect in the trade test used at that time, which was carried out as follows: 100 cc. of the spirit was placed in an ordinary distillation flask of 100 cc. capacity, connected with a condenser and distilled

with a naked flame, at such a rate that the drops fell into the receiver as quickly as possible short of a stream. He stated: "If the object of the test were to conceal the presence of hydrocarbons volatile below 80° C., a better test could not be devised." This remark can hardly apply to the Redwood test *in toto*, as in this the distillation is carried out at a much more reasonable rate. It does, however, apply to the method suggested by Dean in *Technical Paper No. 166 of the United States Bureau of Mines*, "Motor Gasoline: Properties, Laboratory Methods of Testing and Practical Specifications." Dean distils from a standard Engler flask through a special-type condenser, surrounded by cracked ice and water, the distillation being carried out at the rate of not less than 4 cc. and not more than 5 cc. per minute, which is almost as rapid a rate as in the trade test for degreasing benzine. The greater the rate of distillation, the less the presence of low-boiling compounds is capable of detection.

Studying these various tests, it occurred to me that if a method could be devised having the ease of manipulation of the Redwood test, coupled with the same rate of distillation, and yet giving similar results to the Engler test, one would obtain the necessary information about the composition of a motor-spirit from the standpoint of its volatility.

The test I propose to submit to you this evening has been devised with these ends in view. The apparatus (Fig. 1) consists of a small round-bottom flask of $2\frac{1}{2}$ in. diameter, the inside diameter of the neck being 1 in., and its length from the shoulder $1\frac{1}{2}$ in. To this flask, by means of a sound, well-fitting cork, is attached a 4-pear Young dephlegmator column of total length $12\frac{3}{8}$ in., length from bottom to side-arm $10\frac{3}{8}$ in., the beginning of the bottom pear being $3\frac{1}{2}$ in. from the bottom of the column, and the total length of the 4 pears being $5\frac{3}{8}$ in. The inside diameter of the tube from which the column is made is $\frac{7}{16}$ in., and the diameter of the pears is $1\frac{1}{4}$ in. The side tube is bent at an angle of approximately 70°, and is $7\frac{1}{4}$ in. in length. The distillation apparatus is attached to an ordinary Liebig condenser, 22 in. long, fitted with an adapter, to lead the spirit into the 100 cc. graduated reception-cylinder. An accurate thin-stem, small-bulb thermometer is fitted in the top of the column, the top of the bulb of the thermometer being level with bottom of the side-arm. The column is enclosed in a wide tube 8 in. long by 2 in. diameter, the bottom of which is fitted on to a cork, butting on to the cork connected to the flask, while the top of the tube is loosely packed with cottonwool. This wide tube serves to protect the column from draughts, and provides a very

efficient air-lagging. It was suggested by a column designed for a different purpose by Mr. F. Esling, which was protected in a similar manner. In making the test, the column, with its protecting tube, is fitted to the flask, into which have been placed a few small pieces of boiling pot, and then 100 cc. of the spirit to be tested is charged in by means of a pipette through the top of the column. The side tube is now connected to the condenser, and heating of the flask (which is protected by plain iron gauze) is commenced. A little practice soon enables one to estimate the size of flame necessary to bring the liquid to boiling-point at the desired rate.

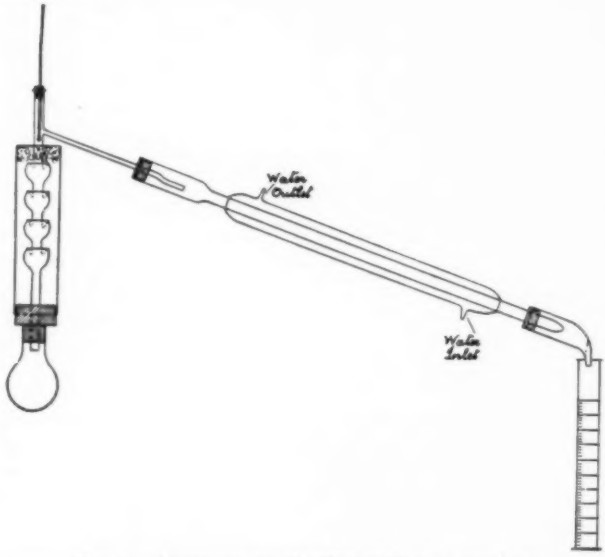


FIG. 1.—Apparatus for Distillation Test, $\frac{1}{8}$ actual size.

The initial boiling-point is taken as that at which the first drop falls from the side-arm. The distillation is continued at the rate of 2·5 cc. per minute. This rate is conveniently timed by means of a metronome, previously so calibrated that, at the rate of one drop per beat, the distillation will be at the required rate.

Readings of the distillates may be taken at any desired points, but for most practical purposes the amounts volatile below 100° C., 125° C., and 150° C., together with the total amount volatile, are all that are necessary. The final boiling-point is taken as that at

which the flask becomes dry, which is usually accentuated by the formation of a white cloud of vapour as a drop from the column falls on the hot bottom of the flask.

I have tabulated the results obtained by this new test on seven different spirits, against results obtained by the Redwood test, and also by the Engler test, using that modification in which, when the temperature, as shown on the thermometer, rises above that of the specified fraction after the removal of the flame, that fraction is considered to be complete.

The results given are the average results obtained from two, three, or four determinations by each method on each sample. Experimental spirits A, B, and C, were prepared from crude oil, so as to give fuels with wide ranges in the percentage of low-boiling constituents. The initial and final boiling-points obtained by the new method are in every case lower than those obtained by the Redwood or Engler tests; as would be expected from the type of apparatus employed. Where the percentage of low-boiling compounds is high, as in the first sample, the percentages volatile below 100° C. approximate somewhat closely, the small percentage of higher-boiling compounds not being sufficient to mask the presence of the lighter ones. As the actual percentage of low-boiling hydrocarbons diminishes, the masking effect in the Redwood distillation becomes more marked, while the results obtained by the Engler and by the new method are so close as to be within the limits of experimental error. This apparatus may be purchased from Messrs. A. Gallenkamp & Co.

It may be of interest here to note the gradual change in the composition of motor-spirits corresponding to the development of the motor-engine during the last decade. In the years 1907–1908, when I had occasion to examine various motor-spirits by the Redwood test, the average percentage of these spirits volatile below 100° C. varied from 60 % to 70 %, and the final boiling-point from 125°–130° C. Blount (*Proc. Inst. Automobile Eng.*, i, 1909) published the results of distillation tests of 19 motor-spirits in which the average percentage volatile below 100° C. was still from 60 %–70 %. The final boiling-points were not given, but the average residue not volatile at 133° C. was about 3·0 %. In 1912 I examined various samples of motor-spirit—Shell, Crown, Pratt's Perfection and Taxibus. The average percentages volatile below 100° C. were respectively 58 %, 42 %, 53 % and 34 %, and the final boiling-points were 151° C., 165° C., 152° C. and 157° C. In table VIII, the last four spirits shown were taken from sealed cans as supplied by the makers in April of this year. There is thus shown a gradual increase in the

Table VIII.

Comparison of Redwood, Engler and New Method Results.

1. Redwood method.
2. Engler method, end of fraction being when thermometer rises above temperature after removal of flame.
3. New method.

Average results of 2, 3, or 4 tests on each sample.

	Experimental Spirit A.			Experimental Spirit B.			Experimental Spirit C.		
	1	2	3	1	2	3	1	2	3
Specific gravity at 15·5° C.	·714	·714	·714	·761	·761	·761	·731	·731	·731
Initial boiling-point	46° C.	42° C.	30° C.	75° C.	56° C.	48° C.	57° C.	42° C.	32° C.
Volatile below 100° C.	78·0%	82·5%	79·5%	8·5%	17·0%	21·5%	29·0%	35·5%	35·5%
,, ,, 125° C.	95·5%	96·0%	95·0%	58·0%	64·5%	64·0%	58·5%	64·5%	63·5%
,, ,, 150° C.	—	—	—	88·5%	92·0%	90·5%	84·0%	88·5%	86·5%
Total distillate	96·5%	96·5%	96·0%	98·5%	98·5%	97·5%	97·5%	98·0%	97·5%
Residue in flask	1·2%	1·2%	2·0%	1·4%	1·2%	2·1%	1·4%	1·3%	2·0%
Loss	2·3%	2·3%	2·0%	0·1%	0·3%	0·4%	1·1%	0·7%	0·5%
Final boiling-point	129° C.	128·5° C.	125° C.	176° C.	174·5° C.	170° C.	185° C.	181° C.	174° C.

	Red Line Spirit.			Mex No. 1.			Pratt No. 2.			Shell No. 2.		
	1	2	3	1	2	3	1	2		1	2	3
Specific gravity at 15·5° C.	·749	·749	·749	·714	·714	·714	·739	·739	·739	·745	·745	·745
Initial boiling-point	59° C.	58° C.	46° C.	46° C.	40·5° C.	33° C.	54° C.	43° C.	39° C.	65° C.	52° C.	41° C.
Volatile below 100° C.	20·0%	28·0%	27·5%	40·0%	46·0%	46·0%	25·0%	33·5%	32·5%	16·5%	23·5%	23·0%
,, ,, 125° C.	65·5%	69·0%	68·0%	71·0%	75·5%	75·5%	64·5%	72·0%	67·0%	57·0%	63·0%	61·5%
,, ,, 150° C.	89·0%	91·5%	90·0%	89·5%	92·5%	92·0%	88·5%	92·0%	90·0%	87·5%	90·0%	88·0%
Total distillate	98·0%	97·5%	97·5%	96·0%	92·5%	92·0%	97·0%	98·0%	97·5%	97·5%	98·0%	97·5%
Residue in flask	1·5%	1·3%	2·2%	2·0%	6·7%	7·4%	1·5%	1·3%	2·0%	1·5%	1·2%	2·0%
Loss	0·5%	1·2%	0·3%	2·0%	0·8%	0·6%	1·5%	0·7%	0·5%	1·0%	0·8%	0·5%
Final boiling-point	181·5° C.	184° C.	176° C.	>200° C.	not taken	not taken	178° C.	177° C.	170° C.	182° C.	180° C.	174° C.

content of higher-boiling compounds which, I hope, has not yet reached its limit. The present day automobile engine will run quite well on spirit which would have given much trouble with the engine of earlier days; and I think it is "up to" the motor engineers to see that the engine of the future will run well on a much less volatile mixture than is employed at the present day. The world's supply of petroleum products suitable for internal-combustion engines is strictly limited, and it is only by development on these lines that the petroleum industry will be able to meet the growing demands of the motor world. At the present time it is a waste of valuable products to use spirits containing an unduly large percentage of low-volatile compounds for road and water vehicles, as these light products assist the vaporisation of heavier products, which in themselves are not satisfactory fuels, but the addition of which, in mixture with the lighter compounds, increases the visible supply of motor fuel enormously. I would suggest the following average specifications for motor-spirits for marine or terrestrial use, using the new method just described:—

	No. 1 Quality.	No. 2 Quality.	Taxibus and Heavy Motor Quality.
Volatile below 100° C. =	25–30 %	15–25 %	10–15 %
„ „ 125° C. =	60–65 %	50–60 %	45–50 %
„ „ 150° C. =	85–90 %	70–80 %	60–70 %
Final boiling-point =	170°–180° C.	190°–200° C.	200°–210° C.

In the case of motor-engines for aerial purposes, I would not care, at the present time, to suggest the lowering of the quality of the spirit in any way.

Sulphur-content.—The detection of combined sulphur in a motor-spirit is, in most cases, made very easy by the characteristic odour of these compounds, although in some cases petroleum spirits may contain comparatively large quantities, and yet have no offensive smell. A little of the spirit may be boiled with a few small pieces of metallic sodium in a flask fitted with a reflex condenser; after cooling, water is cautiously added to remove excess of sodium, and then the aqueous layer may be tested for sulphur-compounds: (1) by placing a little on a bright silver coin, a brown coloration indicating sulphur; (2) by the addition of sodium nitroprusside, which gives a violet coloration if sulphur be present.

Francis and Crawford (*J. Ind. Eng. Chem.*, ix, 479, 1917) give the following qualitative test for sulphur-compounds in petroleum. The oil is heated with excess of sodium, the residue extracted with water, and the solution neutralised with hydrochloric acid, then a

10 % excess of the same reagent is added. A small crystal of *p*-amido-dimethyl-aniline sulphate is then dissolved in the liquid, and several drops of a dilute solution of ferric chloride are added. The presence of sulphur is indicated by the development of a blue coloration, which becomes more intense on standing.

A method for identifying and determining approximatively the sulphur-compounds which react with the metals of carburettors, etc., was devised by myself in 1909, for checking the desulphurisation of spirit in the Works. It consists in distilling 100 cc. of the spirit in a flask in which is placed a piece of chemically-clean copper foil 2 cm. × 1 cm. The copper foil is cleansed by warming it for a few minutes in a 10 % solution of potassium cyanide, then washing with distilled water, and finally with a few drops of absolute alcohol. It is then dried by pressing between filter paper, and immediately placed in the spirit to be tested. Notes are made of the amount of stain (copper sulphide), and the period of the distillation at which the stain first shows. By calibrating these points against spirits of known sulphur-content, a good and quick approximation of the sulphur-content of the spirit may be made.

Sanders (*J. Chem. Soc.*, ci, 358, 1912) describes a similar test, in which copper turnings are used. The film of copper sulphide is afterwards dissolved by potassium cyanide, and the sulphur estimated by boiling with bromine water and hydrochloric acid, and precipitating as barium sulphate in the usual way.

Determination of total sulphur.—The most usual methods of determining the total sulphur are:—

(1) By burning the spirit in a current of air, absorbing the products of combustion, and estimating the sulphur volumetrically as sulphuric acid, or gravimetrically as barium sulphate.

(2) By combustion in oxygen under a pressure of 20–30 atmospheres in a calorimetric bomb, and estimating sulphur gravimetrically as barium sulphate.

Both these methods give reliable results, but where the proportion of sulphur falls below 0·03 % by weight, the determination in the calorimetric bomb requires more skilful manipulation. Only 0·5 to 1 gramme of the spirit can be employed in the determination, and this would only give from 2 to 4 milligrammes of barium sulphate, according to the amount of sulphur present. The percentage of error in handling such small quantities of precipitates may be considerable.

Allen (*Analyst*, xiii, 43, 1888), Heusler (*Z. angew. Chem.*, viii, 285, 1895), Engler (*Chem.-Zeit.*, xx, 197, 1896), Kissling (*Ibid.*, 199, 1896), Fischer (*Z. angew. Chem.*, x, 302, 1897), Friedländer

(*Chem. Ind.*, xxii, 343, and *Arb. k. Ges.-A.*, xv, 365, 1899) and Maturin (*Z. angew. Chem.*, xviii, 1766, 1905) absorb the products of combustion in dilute sodium- or potassium-hydroxide solution, complete the oxidation with bromine water, and precipitate the sulphates thus formed with barium chloride in the usual way.

Sanders (*J. Chem. Soc.*, ci, 358, 1912) burns the spirit in a lamp made from a platinum crucible, which is gently heated to dull redness after all the oil is burned. Products of combustion are absorbed by a dilute solution of sodium peroxide, and sulphur estimated as barium sulphate.

Magruder (*Proc. Va. Chemists' Club*, i, p. 53, 1909) describes Burton's method of absorbing the products of combustion in normal sulphuric acid, and titrating against normal sodium carbonate, with co tropaoline as indicator.

Schulz (*Petroleum*, viii, 585, 1913) absorbs the products of combustion in a neutral solution of 30 cc. of 3 % hydrogen peroxide and 30 cc. of water, and titrates the acid formed by N/10 alkali, using methyl orange as indicator.

Schenk (*Chem.-Zeit.*, xxxviii, 83, 1914) volatilises the spirit by means of a current of air, in a specially constructed vessel, and burns the issuing carburetted gas. The products of combustion are absorbed in hydrogen peroxide, and the sulphuric acid estimated volumetrically.

Bradbury and Owen (*Chem. News*, cx, 163, 1914; cxi, 39, 1915) describe an ingenious carburettor for vaporising the petrol by means of air, and then burning the carburetted gases in a Bunsen flame under a spiral of platinum wire heated to bright redness, to ensure complete combustion. The products of combustion are absorbed in perhydrol (a concentrated solution of hydrogen peroxide), and the sulphuric acid estimated volumetrically.

Hewett (*Gas J.*, cxxxvii, 72, 1917) draws air through the spirit, and then passes the air-vapour through a silica tube heated to redness. The products of combustion are absorbed by a solution of caustic soda, oxidised with bromine or hydrogen peroxide, and estimated as barium sulphate.

Conradson (*Eighth Int. Congr. Appl. Chem.*, Sect. 1, Orig. Comm. i, 133, 1912) states that sulphonates and sulphates are not determined by the ordinary lamp-methods, as they remain in the wick and are not burnt. They are determined, however, by calorimetric combustion. He suggests the following methods for the estimation of these bodies:—(1) Only the total sulphur-content as sulphonates and sulphates required. After combustion of spirit, cut wick into small pieces, digest with 0·2 gramme of sodium

carbonate and 5 cc. concentrated nitric acid until the fibres are disintegrated. Add 2 grammes magnesium nitrate, and raise the temperature gradually until the organic matter is destroyed. Determine the sulphur in the residue as barium sulphate in the usual way. (2) Separate determination of sulphur as sulphate and sulphonate Boil wick with baryta solution, then dilute solution and filter. The filtrate contains the sulphonates, and is oxidised with bromine and hydrochloric acid, and sulphur estimated as barium sulphate. Sulphates estimated in wick as before.

Mr. Esling, one of my colleagues, has designed an apparatus and method for the determination of sulphur in motor-spirit, which combines the advantages of giving reliable results with quick determination. It depends on complete combustion of a mixture of petrol and alcohol in a good current of air, the product of combustion being absorbed by a definite quantity of a standard solution of sodium carbonate, which is afterwards titrated against a standard solution of sulphuric acid, using methyl orange as indicator. By mixing the spirit with alcohol, imperfect combustion is averted, and by burning the lamp to dryness on the petrol-alcohol mixture, and afterwards burning two or three successive small quantities of alcohol alone, combustion of all the petrol used is assured. The solution of sodium carbonate is made $\frac{1}{16}$ normal, 1 cc. of such a solution being equivalent to 0·001 gramme of sulphur, and the solution of sulphuric acid for titration is made exactly one-half this strength, i.e. N/32.

The apparatus (Fig. 2) consists of a specially-devised lamp, made entirely of glass, the centre tube carrying the cotton wick being sealed into the head of the lamp, and passing almost to the bottom of the container. The head is ground into the container, making a tight joint, and a small stoppered side-arm serves for the introduction of alcohol in the subsequent washing out. The capacity of this lamp is about 10 cc. The absorption-apparatus consists of a chimney, conveniently made by sealing an ordinary wide test tube on to narrow glass tubing, which is bent into a semicircle, and fitted by means of a cork into the first chamber of the absorption-tube. This chamber is left empty, and acts as a partial condenser of the products of combustion. The second chamber is packed with clean glass wool, moistened with 20 cc. of the standard sodium carbonate solution, which acts as an efficient scrubber for the gases. To the top of this tube is fitted a splash-preventer which stops the carry-over of any liquid by the aspirated current of air. After complete combustion, the whole of the absorption apparatus is well washed out with distilled water, the

washings bulked, and the amount of sodium carbonate neutralised is estimated by titration. This method is easily worked and gives very concordant results. The results have been checked gravimetrically by oxidation and precipitation as barium sulphate in the usual way, and agree very closely.

	Volumetrically.	Gravimetrically.
(1) Average results of 4 tests ...	S = 0·0740 %	S = 0·0737 %
(2) „ „ „ ...	S = 0·0275 %	S = 0·0281 %

Calorific value.—This is easily determined in the usual manner in any good bomb calorimeter, provided suitable precautions are used to obtain complete combustion. The pressure should be at least 25–30 atmospheres to ensure this. The spirit may be introduced into the platinum capsule of the bomb by means of a Lunge & Rey pipette, or may be sealed in a thin glass bulb, which collapses on charging the bomb with oxygen.

Rosenhain (*J. Soc. Chem. Ind.*, xxv, 239, 1906) has described a calorimeter for the estimation of the calorific value of volatile liquids, in which the substance is absorbed by a pellet of kaolin or a piece of porous refractory material, which is then wrapped in tin foil.

Claim is made for a more accurate weighing of the material and more complete combustion than in the case of the bomb calorimeter.

Rawles (*J. Soc. Chem. Ind.*, xxvi, 665, 1907) has modified Darling's calorimeter for the purpose of determining the calorific value of petrol. In this modification the petrol is burned at atmospheric pressure in a current of pure oxygen.

Determination of hydrocarbon characteristics.—The accurate determination of the various hydrocarbon contents of a motor-spirit is a matter of great difficulty, and does not come within the scope of a technical test, certain chemical tests can, however, be applied, which enable us to approximately determine two of the series which may be present in motor-spirit.

Olefines.—These compounds combine with hydrobromic and hydriodic acid, absorb bromine and iodine, are dissolved by concentrated sulphuric acid (1·84), oxidised by potassium permanganate, and converted by hypochlorous acid in aqueous solution to chlorhydrins.

Balbiano and Paolini (*Chem.-Zeit.*, xxv, 932, 1901) treat 2–3 cc. of the sample (with shaking) with 10–12 cc. cold saturated solution of mercuric acetate, and set aside in a closed tube for 24–36 hours. If the aqueous layer is turbid from the presence of small white lustrous lamellæ, the presence of olefine is proved.

Most of these methods, however, are unreliable if sulphur-compounds are present, the sulphur-compounds reacting with these reagents.

Olefines are usually estimated by:—

(1) Shaking up the spirit with an equal volume of strong sulphuric acid in a graduated tube, and noting the decrease in volume of the spirit.

(2) Bromine or iodine absorption. Routala (*Chem. Centralbl.*, 1912, ii, 638) states that reliable results can only be obtained in this way if time of action, temperature, degree of exposure to light,

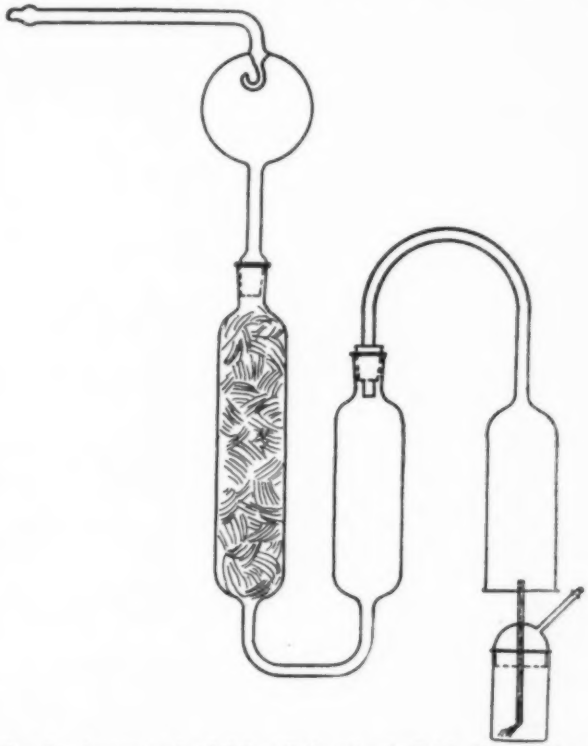


FIG. 2.—Apparatus for Sulphur Estimation in Spirit, $\frac{1}{3}$ actual size.

and quantity of halogen be kept constant. From the bromine value, the percentage of olefinic hydrocarbon A can be calculated from the formula

$$A = [K + (n\text{-}5)c\,]\,Br,$$

where n is the mean number of carbon atoms (at least 5) of the molecules of the olefinic hydrocarbons boiling within the same

limits as the substance, Br is the bromine value, K and c are constants. The value of $c = 0{\cdot}0875$, while $K = 0{\cdot}4375$ for amylene, 0·5950 for hexylene, 0·6075 for heptylene, and increases by about 0·0875 for each additional CH_2 group.

Example.—A mixture of amylene and isopentane has sp. gr. 0·6424 @ 15° C., and bromine value 138; hence the mixture contains $0{\cdot}4375 \times 138 = 60{\cdot}37$ % amylene.

The oil to be tested is treated in the dark for 15 minutes with a solution of bromine in carbon bisulphide, excess of potassium iodide is now added, and the amount of liberated iodine estimated by means of sodium thiosulphate solution.

(3) By decomposition of potassium permanganate. The oil is shaken frequently for about 15 minutes, with a standard solution of potassium permanganate acidified with sulphuric acid; and the amount of potassium permanganate destroyed is estimated by ferrous ammonium sulphate.

These three methods only give approximate values for the olefine content, as they are all affected by secondary reactions.

Aromatic hydrocarbons.—These bodies are detected by the smell on treating a sample of the spirit with strong nitric acid. Various methods have been devised for estimating them quantitatively. The method proposed by Krämer & Bottcher, based on the diminution in volume by shaking the spirit with a mixture of concentrated and fuming sulphuric acids, has been modified by Dunstan & Thole, who first shake the spirit in a stoppered graduated tube with ordinary strong sulphuric acid, and then repeatedly shake with fuming sulphuric acid containing 3–4 % of free sulphuric anhydride, until there is no further reduction in volume. The spirit and acid are kept cool during the process, and thus the possible sulphonation of paraffins and naphthenes is obviated. The preliminary treatment with strong sulphuric acid removes any olefines, and also certain sulphur-compounds. It is worthy of note at this point that the residual spirit from this treatment, after neutralising with caustic soda and re-distilling, has practically the same odour, no matter what the source and smell of the original spirit.

Engler suggests the removal of olefines by boiling with mercuric acetate, and then the detection of the aromatic hydrocarbons by means of the formolite reaction—that is, treatment of the spirit with a mixture of formalin and sulphuric acid.

Ballantyne (*Proc. Inst. Automob. Eng.*, iii, 294, 1909) gives the following method for the estimation of aromatic hydrocarbons:—

To 25 cc. of the sample add slowly, with constant agitation and

keeping below 50° C., a mixture of 25 cc. nitric acid (sp. gr. 1·42) with 25 cc. of sulphuric acid, which has previously been cooled to 20–30° C. After the whole of the acid is added, heat to 60° C. and keep at that temperature for half-hour with frequent agitation. Pour into separating funnel and run off acid layer. To the mixture of nitro-bodies and petrol add sufficient nitric acid (sp. gr. 1·5) to dissolve out the aromatic nitro-bodies; separate, wash with 5 or 6 volumes of water, and measure volume. This volume multiplied by 0·85 gives volume of the corresponding aromatic compounds.

Halphen (*Les Matières Grasses*, iii, 1,987, 1910) treats the spirit in a similar manner, but absorbs the nitro-bodies with strong sulphuric acid, measuring increase in volume of acid, and using 0·87 as the multiplying factor to determine volume of aromatic hydrocarbons.

Another method is to measure the non-nitrated bodies remaining, obtaining the volume of aromatic hydrocarbons by difference.

It is hardly necessary for me to mention the excellent method which was brought before the Institution earlier this year by Mr. Bowrey (*J. Inst. Petr. Techn.*, iii, 287, 1917), in which the aromatic hydrocarbons are extracted at low temperatures by liquid sulphur-dioxide, and then separated by fractional distillation.

All these methods are easy of manipulation, and give fairly reliable results.

Spontaneous ignition temperature.—Moore (*J. Soc. Chem. Ind.*, xxxvi, 109, 1917) has recently described a method of determining this factor in petrols.

The test consists in allowing one drop of the fuel to fall into a platinum crucible heated to a desired temperature. If the temperature is much higher than the ignition-point, a sharp explosion takes place almost immediately; if below the ignition-point, no explosion will occur. The lowest temperature at which an explosion takes place is called the spontaneous ignition temperature. This temperature is of great interest to automobile engineers, with relation to the compression limits. It is well known that benzol and alcohol will stand higher compressions without pre-ignition than will petroleum spirit; the reason for this is to some extent explained when we know that the spontaneous ignition temperatures in pure oxygen are as follows: benzol 100%, 566° C.; alcohol 395° C.; and petrol 270–280° C., these temperatures being higher in air than in pure oxygen. Further experiments, however, are required before the method can be employed as a standard test.

This paper has been read in order that it may induce discussion, and possibly show the need for the adoption of British standard tests and specifications for motor-spirit.

DISCUSSION.

The President took the opportunity of referring to Mr. Lomax's paper in connection with one or two points that he had in his mind. He first of all noticed that the results shown by the proposed new method were approximately the same as those achieved by the Engler method, but apparently the advantage claimed was that the method was quicker than that of Engler. The speaker, however, would like to know what advantage (if any) it had over the Redwood method. The proposed method showed, of course, a larger percentage of fractions boiling even at low temperatures, but he would ask whether the result obtained was not largely empirical, and that of the Redwood method a more accurate representation of the values of different qualities of spirit; he would like to have the author's views with regard to that point. It appeared to the speaker that what was wanted was not a test indicating an excessive and almost fictitious percentage of low-boiling fractions, but one which showed as accurately as possible the actual boiling-points, and that when a method had been evolved which gave this result in a ready and simple manner, it should be accepted by all branches of the trade and standardised. When once we had a definite standard to work upon, it did not, for purposes of comparison, matter whether the percentage of low-boiling fractions was shown at a high or low figure.

Prof. J. S. S. Brame welcomed the paper which Mr. Lomax had put before the meeting, whom he thought would be amply rewarded for the trouble he had taken if it gave rise to a good discussion by the members of the Institution. Certainly in this country no body of men was so capable of dealing properly with the question of standardisation of methods, and possibly the drafting of a standard specification, as the members of the Institution. He foresaw, however, one difficulty in relation to establishing what might be called a standard specification for petrol. Mr. Lomax had himself called attention to the very great changes which had taken place in the composition of petrol within the last few years; and, in an endeavour to use a larger percentage of the crude oil, it was quite possible that there would be still further changes in the direction of increasing the quantity of the heavier distillates present. There could, however, be no doubt that the questions of analysis, determination of physical constants, and so on, were subjects which should be taken up by a representative committee of members of the Institution; and it should be composed, not only of the chemists, but one on which the interests of

traders and users should be represented by the inclusion of one or more nominees from such a body as the Automobile Association. Garry and Watson, in 1904, put forward a paper very much on the same lines (*Journ. Soc. Chem. Ind.*, vol. xxiii., pp. 701–704), showing the effect of different forms of apparatus on the yield of products obtained during the distillation of petrol. Broadly speaking, their results agreed with those which Mr. Lomax had laid before the members that evening. He thought that the meeting would be in general agreement with Mr. Lomax that it was time that specific gravity, as a test of the quality of the petrol, should be shelved, and that volatility should be relied upon.

In testing aviation spirit, he had used the plain flask, the four-bulb column, similar to that shown by Mr. Lomax, and the dephlegmator devised by Young and Thomas, which they regarded as a most efficient form of dephlegmator; his results convinced him that it was so. It would be realised how varied might be the results obtained by different investigators with various apparatus, unless the methods were standardised.

He exhibited a pear-shaped flask which he had found very useful, giving an advantage over the round-bottomed flask for distillation purposes. The advantage of the conical bottom was that it was possible to get to the very last portions of the distillate without risk of cracking the flask.

Broadly speaking, if the method of distillation were standardised, the distillation figures would be an excellent measure of the degree of volatility of the spirit. He thought, however, that in coming to any conclusion as to the best form of apparatus which should be employed, it was very desirable that the figures obtained by distillation should be compared with the actual figures for vapour-pressure of the petrol at different temperatures. He did not desire to be understood as regarding the vapour-pressure test as a commercial test; it was far too elaborate and complicated. But in getting the proper interpretation of the distillation test, he felt that in any investigation of the latter the actual vapour-pressure curves should be available for comparison.

Mr. Lomax had described some of the methods for determining calorific value, and had laid emphasis on the bomb calorimeter, which, while giving very good results, had the advantage that the necessary material for sulphur estimation could be obtained at the same time. He would like, however, to refer to two methods which Mr. Lomax had not mentioned, because he thought they would be worthy of consideration when that happy stage of laying down standard methods was reached. Prof. W. Watson, in the

earlier stages of his classical work on the combustion of petrol in engines (*Journ. Roy. Soc. Arts*, vol. lviii., p. 990; 1910), determined the calorific value by carburetting air with the petrol, which was completely vaporised drop by drop, and then burning the mixture in a Boys calorimeter. Again, Immenkotter suggested the use of a lamp of the "Primus" pattern, in conjunction with a Junker gas calorimeter. The speaker had carried out a number of tests, using an ordinary benzoline blast-lamp; the results had not been quite up to his expectation in the matter of agreement, yet they showed that the method was certainly one worthy of consideration. There was the advantage in this method that the gross and the net calorific values could be determined simultaneously. In addition, it had the great advantage that 5 or 10 grammes of petrol were used, a fair quantity for the determination, while a series of tests could be run on one charge of the lamp. In conclusion the speaker hoped that an excellent discussion would follow, and that as a result there would be some action taken in order to bring about the very desirable standardisation so admirably outlined by Mr. Duckham.

Dr. Mollwo Perkin had been much interested in reading the paper, because the subject was one which the Institution was quite in a position to take up. Mr. Duckham had practically said what the speaker himself had said. He thought the method adopted by Mr. Lomax was extremely ingenious, and took matters back to the commercial dephlegmator, which, for the purposes of good separation, was lagged. Mr. Lomax had lagged on a laboratory scale by a method which would certainly yield much better results. The speaker had recently had a great deal of work in connection with the separation of benzol and toluol, to which Mr. Lomax had referred in the paper, and it was extremely difficult to get really good separation on a small scale. One of the reasons for this was, that, unless the dephlegmator could be lagged or protected by some such method as that adopted by Mr. Lomax, widely varying results might be obtained by different investigators; in fact, deviations in conditions and results were almost a certainty. He would suppose, for instance, that a door or a window were open, the same separation would not be obtained as with the door or window closed. He had adopted the practice of putting a towel or duster round the dephlegmator, but, of course, Mr. Lomax's method was very much better, giving a much more satisfactory and even result.

He thought that what Prof. Brame had said in regard to the calorimeter was extremely valuable. In dealing with petrol, working with an ordinary bomb calorimeter it was necessary to

use very small quantities, and there was the danger of explosions, although he, personally, had not experienced any. Again, in regard to sulphur, the small quantities employed required, as Mr. Lomax had said, careful manipulation in order to get satisfactory results.

He thought undoubtedly the Institution should lay down a standard for all the English-speaking people—probably a much wider range than before the war. Standards were needed for petrol distillation, for sulphur in the petrol and for other oils as well. Mr. Lomax's process appeared to the speaker to be very satisfactory at present. It seemed to the speaker that the Institution ought to appoint a small committee—he did not like big committees—and ask for the co-operation of members of the Association to bring forth processes, so that a method might be standardised. He quite agreed with Mr. Lomax in thinking that specific gravity as a factor in testing ought certainly to go by the board, although it was a very useful guide to the chemist as to the composition of the oil.

Sir Boverton Redwood was glad that the subject of the testing and standardisation of motor-spirit had been brought before the Institution at the opening meeting of the new session. The question was one of the highest importance, and Mr. Lomax was in the enviable position, denied to some, of being able to devote a large amount of time to the investigation of which he had given the valuable results contained in his paper. He supposed it was only to be expected that he should say something about the author's reference to what is known as the "Redwood" test for motor-spirit. The speaker desired to make it clear at once that neither he nor his brother, nor Mr. Berry, their chief chemist, had viewed the Redwood process as other than susceptible of improvement; they had certainly endeavoured to keep an open mind about it, but, to be quite frank, he thought more highly of the process in question after hearing Mr. Lomax's paper than he had previously done. Obviously, the primary object of a test of that kind was to enable a determination to be made of the relative fitness or suitability of different motor-spirits for the purpose for which they were intended; and it should be borne in mind that the conditions prevailing in the carrying out of the operation of fractional distillation were different from those which existed in the actual use of the spirit, in a motor-car engine, for instance. He was bound to say that, at present, he was not satisfied that the Lomax test was better than the Redwood test as a guide to the probable behaviour of a given sample of motor-spirit when used in practice. He had that morning had an opportunity of conversing with his brother

and Mr. Berry about Mr. Lomax's paper, and he was in a position to say that, broadly, these gentlemen shared the view he had just expressed. Nevertheless, he congratulated Mr. Lomax upon the manner in which he had dealt with the subject, and the speaker's only suggestion was that Mr. Lomax should continue his investigations, correlating the results of the various systems of testing which he had placed before the Institution with the actual, practical results obtained from the use of similar samples of spirit in a motor or internal-combustion engine on the test bench. He hoped the author would do that before definitely committing himself to an advocacy of the adoption of the Lomax test.

Dr. Dunstan wished to congratulate Mr. Lomax on bringing forward this important matter on two counts: firstly, because the subject was one of wide interest, and, secondly, because Mr. Lomax had given time for discussion, which, in the past, few authors had attempted to do. He supposed that it was a question of the exigencies of time and space that prevented Mr. Lomax from mentioning such fuels as benzol, light shale oil, and the products of low-temperature carbonisation of all sorts of bituminous materials. In the future a multiplicity of motor fuels would have to be dealt with, and no one test could ever be satisfactory. He had a case in point, in which the motor fuel was entirely volatile below 100° C., free from objectionable smell, devoid of sulphur, and had a high calorific value; it nevertheless suffered from the drawback that it became solid at a relatively high temperature. Obviously, therefore, a setting-point test, as well as a distillation test, was necessary to meet cases of that sort.

With regard to the estimation of vapour tension as against boiling-point, the speaker was not quite in agreement with Prof. Brame. If a method could be adopted—similar to that used by Ostwald, Will and Bredig in their molecular-weight experiments—whereby a sample of, say, 10 grammes weight was taken in a potash bulb, maintained at a temperature of 150° F., and subjected to a current of dry air, that, of course, would give a measure of the vapour-tension, while the time required for the apparatus to become dry would similarly give a comparison between the volatilities of particular spirits. After all, as it seemed to the speaker, the vapour-tension was the controlling factor; the higher this tension, the more likely the success of the spirit. Moreover, these tests had to simulate what went on in the engine carburettor, and it was not of much use to undertake tests more delicate than the capabilities of that instrument; the comparison should indicate fairly well how the individual spirit would behave in working.

The first section of the paper dealt with the hydrocarbons present in ordinary motor-spirit, a fruitful field of research for a chemist anxious to find a line for himself. It was remarkable, at this time of day, how little definite knowledge was possessed of the components of motor-spirit; in no one case, with the possible exception of the Pennsylvania spirit, did more than an approximate notion of the chief components exist. In table III of the paper, Mr. Lomax had mentioned various derivatives, and one that had attracted the speaker's attention in the *cyclo*-paraffin series was 1·1· dimethyl *cyclo*-propane. He did not know who isolated that particular hydrocarbon. The speaker's experience with the three- or four-membered "ring" hydrocarbons was that they were rather unstable, and that, while they might occur in the original petroleum, it was doubtful whether they would survive the processes of refining and distillation. Stable ring-compounds were those with five or six atoms of carbon to the ring. It was rather astonishing how prevalent the *cyclo*-paraffins were. In a number of spirits he had examined he had found the hexa-hydro-toluene that Mr. Lomax had referred to. It was a curious thing that the *m*-compounds were those which seemed to turn up with great regularity; in coal-tar and other mixtures of hydrocarbons, natural and artificial, Mr. Lomax had not mentioned fully and completely all the hydrocarbons determined in motor-spirit, and the speaker would draw attention to a case which Dr. Thole and he had recently handled, and which, from a chemical point of view, was somewhat curious. Dr. Dunstan then proceeded to symbolise this case on the blackboard, remarking that a series of homologues was present, the first member being C_{10} H_{18}, characterised, among other things, by extreme stability and high specific gravity. So far not much had been done to determine their structure, but he thought it must be assumed that a body of that sort contained the ring found in the case of camphor and other commonly recurring camphene compounds. If so, it was a very remarkable point of comparison between natural oil and the products of the ordinary organic synthesis in nature, and seemed to afford an additional piece of evidence of the organic origin of petroleum.

With regard to specific gravity, all were agreed as to the need for the abolition of that as a test; while, however, it existed, it was well that members should make up their minds as to the necessity of comparable conditions. The physical chemist worked at 25° C., and determined absolute density, not specific gravity. The actual mass per cc. was measured, and the volume of the pycno-

meter determined once for all. Preferably silica apparatus should be used on account of its negligible coefficient of expansion. Hence, no matter what the temperature of the determination, the volume remained constant, and it was easy to get absolute density in place of specific gravity. The speaker considered that one aspect of the distillation test might be standardised—namely, the determination of the initial boiling-point. There was, obviously, always the risk of the thermometer bulb not keeping up with the temperature of the vapour, and if that happened there would be a big lag in the rate at which the thermometer took its record. The speaker noted that Mr. Lomax specially advocated small-bulb thermometers in this connection.

The lamp-method for estimating sulphur was, of course, very ancient, and the speaker supposed that it dated back to the referee gas tests. Dr. Coleman had shown him an ingenious apparatus for estimating the sulphur in benzol, in which sodium peroxide was used as oxidising agent. Dr. Dunstan was, however, not sure that an oxidising agent was required. In the presence of a good access of air, the sodium sulphite became sulphate. Fig. 3 illustrates the details of the lamp used by Dr. Thole and himself, which is operated as follows :—

Ten cc. of motor-spirit are pipetted into the lamp, and mixed with 10 cc. of absolute alcohol. The absorbent is dilute potassium or sodium hypobromite. After the lamp has burnt out there is added a little more alcohol, the burning is continued to rinse out the last traces of spirit, the absorbents are washed out, and the sulphur estimated in the usual manner.

In connection with the determination of sulphur in benzol, Hewitt had found that thiophenes tended to escape unburnt, and he (the speaker) could from his own experience state that this class of compound was notably difficult to oxidise. In such a case an 18-in. length of silica tube, packed with spongy platinum, and heated red-hot, could be interposed between the lamp and the first absorbing tube.

Any lamp apparatus should be carefully checked by burning in it a spirit whose sulphur-content had been determined by the best method of all, namely, that of Carius. It should further be noted that the lamp method fails to estimate sulphur present as sulphonic acid or as free sulphuric acid unless the wick is afterwards treated, a complication which somewhat detracts from the utility of this otherwise excellent process.

Mr. W. M. Guttentag stated that his impression was that the Engler method as employed to-day was used with a modification

introduced by Ubbelohde, and in that modification the distillation was not stopped at 150° C., but was continued and carried on until the flask was dry. On comparing the results of distillations, made by this method, from various sources, it was found that the agreement was remarkably close. It therefore occurred to the speaker that this was a sufficiently good method. Possibly by taking a larger quantity, and using a dephlegmator, the same results might be obtained as with the more complicated apparatus suggested by

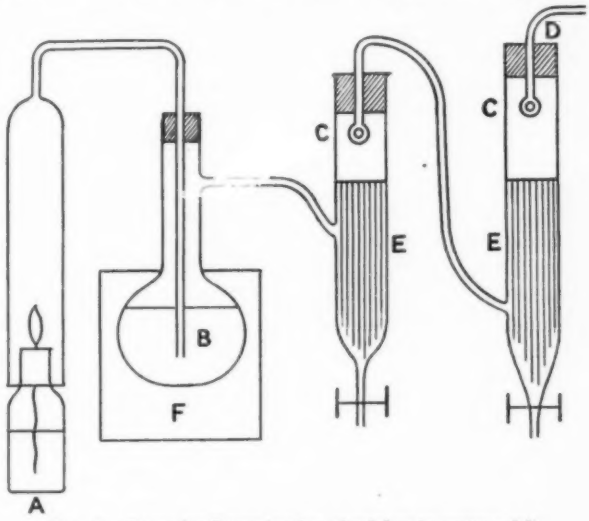


FIG. 3.—Lamp for determination of sulphur in motor-spirit.

A. One-ounce bottle with mixture of motor-spirit and alcohol, and a silica wick-holder.
B. Flask with solution of potassium hypobromite.
C. Anti-splash traps.
D. Suction of air-pump.
E. Lengths of thin glass tube, immersed in solution of KO Br.
F. Cold water.

Mr. Lomax. Although the specific gravity question had been somewhat set aside, he (the speaker) considered it of value, particularly from the point of view of checking the quality of the spirit when transported from one end of the country to the other; if on arriving at its destination the spirit was found to have a gravity differing from that at which it started, something had happened in transit. There was also another point of view. It was some-

times interesting to study specifications for aero-engine fuel, where the question of specific gravity entered: with the lighter gravity there was an increase in calorific value, in addition to the reduction in weight, bulk for bulk, a definite advantage in lighter spirit for aeroplane engines. Absolute calculation as to which was the best spirit was probably somewhat involved. An apparatus of interest in connection with specific gravity was a combination of the hydrometer with the thermometer, the hydrometer with a mercury thermometer inside, a very useful form, which he had not seen in this country.

With regard to distillation, Mr. Lomax might have met with the suggestion that a petrol, say, of boiling-points between 50° and 150° C., might be equal in fuel quality to one the boiling-points of which range from 60° to 140° C.

He would like to ask the author a question as to the iodine value of petrols. Was it possible to state to what extent unsaturated hydrocarbons were dangerous or disadvantageous in a motor fuel? The tendency was, perhaps, to regard them as perfectly harmless.

As another point of interest, he would refer to the value of plotting the results of distillation figures in the case of the larger quantities of petrol, giving very useful curves from a comparative point of view.

With regard to the acid content of petrol, this was a possible source of trouble, though but rarely.

With respect to the initial boiling-point of distillation, as practised to-day, the first drop from the flask was recorded, and also the first drop from the receiving cylinder, and these results seemed to have served fairly well, sufficiently at any rate for routine practice.

Prof. Cadman desired to add a word of congratulation to the author for his very interesting paper, and at the same time to offer one criticism in connection with the figures given in table III. Mr. Lomax had put forward a plea for careful investigation with respect to the standardisation of methods. But the evidence which the author had recorded appeared to be a comparison of three different methods with seven different spirits. If the intention had been to put the table forward as evidence in support of standardisation, he ventured to think that Mr. Lomax would have done better to have taken a long series of tests by each method, using the same spirit for each series.

Mr. Lomax, replying to the discussion, said, in relation to the President's remarks, that the one advantage which he claimed for

his method over the Redwood test was that the former showed the presence of low-boiling constants; this the Redwood test did not do. This he had shown in table VII, columns 4 and 5. These were mixtures containing certain percentages of benzene, in which the Redwood test did not show any benzene. In each case the initial boiling-point was higher than the final boiling-point of the original benzene used. The only advantage he claimed over the Redwood test resided in that fact, that the light hydrocarbons, when present in only small quantities, were not so masked by the heavy hydrocarbons.

He was much interested in Prof. Brame's figures, which seemed to confirm the necessity for a closer estimation in testing. The lower-boiling hydrocarbons undoubtedly exercised a great influence on the vapour-pressure. A hydrocarbon having a boiling-point of 125° would have a low vapour-pressure at zero or 10° C. The speaker had thought of estimating the calorific value in such a calorimeter as the Junker or Boys calorimeter, but the difficulty of getting complete combustion of the spirit had not yet been overcome, and he thought much more reliable results could be obtained from the bomb calorimeter; he had never had any explosions with the bomb calorimeter. He thought that Sir Boverton Redwood's suggestion that laboratory tests should be checked against practical bench-tests of engines was a sound one. There had in the past been no correlation between the two methods. The chemist in the laboratory tested a given petrol in a certain manner, but did not, in ninety-nine cases out of a hundred, know what the engineer had in view. Both tests should be applied, as a mutual check upon the trustworthiness of the methods adopted. At the present time there was no chemical method of testing petrol which would in itself indicate the probable behaviour in actual practice.

With regard to Dr. Dunstan's suggestion of passing a current of air through the petrol, that course was proposed by G. H. Baillie in 1908 (*Engineer*, cv, 504). Air was blown with a pump through a definite volume of spirit, noting the volume at every ten strokes of the pump, until all had been vaporised.

In relation to the compounds upon which doubt had been suggested, he had taken the references from Beilstein and Richter, who claimed to have discovered these compounds in petroleum.

It was rather difficult to say what should be taken as a standard for the initial boiling-points. He had tested petrols in which, before there was any drop from the side arm of the flask there had been several from the end of the condenser; in those cases, the

initial boiling-point taken as the first drop from the side arm would be altogether wrong.

With regard to Mr. Guttentag's remarks, it was evident that the Engler test as used by Ubbelohde was very similar to the Redwood test. Taking a larger quantity, and using a still-head, gave more indication of the composition of a spirit, but took much longer than the ordinary test.

The specific gravity would always be of commercial value in transporting petrol and checking its removal. The spirit might have a specific gravity of 0·715 when it left the Works, and of 0·720 when it reached its destination. There had been a general experience of that sort in connection with cargoes coming from abroad.

On the subject of aero-engines and the question of heavy as against light motor-spirit, the speaker did not think that the specific gravity mattered very much. With the heavier spirit the calorific value was practically the same per unit of weight, and, except that it perhaps involved a slightly larger tank, the volume did not matter.

As to the amount of unsaturated hydrocarbons in petrol, cracked spirit certainly contained a large amount of these bodies; some were satisfactory while new, and others were very unsatisfactory at all times.

In reply to Prof. Cadman, he would say that in all the tests three or four distillations had been carried out with the same spirit, and the average of each series given. Taking, for instance, table VIII, in no. 1, the Redwood method, the average given would probably be that of four or five tests, and so with the other methods, never less than two tests being made with the same spirit.

The President was sure all had listened with great interest to Mr. Lomax's paper and the discussion. He thought Mr. Duckham's suggestion for the formation of a committee to consider the question of standardisation most excellent, and was confident that the Council would give the matter full consideration. He then proposed a hearty vote of thanks to the author for his very valuable and interesting communication.

This vote was passed by acclamation.

Twenty-fifth General Meeting.

A Meeting of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2, on Tuesday evening, 20th November, 1917, Mr. Charles Greenway (President) occupying the Chair.

The Members of Council present were Mr. Barringer, Professor John Cadman, Messrs. E. H. Cunningham Craig, Arthur W. Eastlake, and Sir Boverton Redwood, Bart.

The Hon. Secretary (Mr. Arthur W. Eastlake) announced that the following gentlemen had been elected:—

As *Members*:—Alexander Clubb, Owen David Lucas and Tom Macindo McKenzie. As *Associate Member*:—Reginald John Ward; and as *Associate*:—David Bruce Richardson.

The President, in calling upon Mr. W. H. Dalton to present his paper "On the Oil Prospects of the British Isles," remarked that the subject was one of the very greatest importance at the present time. As a result of the war, attention had been directed to the vital necessity for developing, as far as practicable, the oil supplies of the Empire, particularly of the British Isles, and all would listen to what Mr. Dalton had to say with great interest. Not being a distinct speaker, Mr. Dalton had deputed the reading of the paper to Mr. Edward Holiday, a son of our late member, Mr. F. A. Holiday, whose excellent account of the Uralsk oilfields, delivered before the Institution on 21st December, 1915, would be well remembered, and whose decease within twelve months of that time was a matter for deep regret. He had therefore much pleasure in calling upon Mr. Holiday to read the paper.

On the Oil Prospects of the British Isles.

By W. H. Dalton, F.G.S., F.C.S., *Member*.

The preparation of this article has been reluctantly undertaken at the earnest request of some influential members of the Institution, which constitutes perhaps some apology for the trespass upon your patience. The infliction would have been more severe if you had had to listen to the writer's elocutionary incapacity, but the friendly services of his substitute will do much to modify your *ennui*.

It may be as well to state at the outset that the writer here deals only with actual liquid petroleum, not with the potentialities of distillation from so-called oil-shale, from coal, peat, or any other carbonaceous solids. On the other hand, the occasional discharges of gas are largely composed of hydrocarbons, and to this extent

are truly petroleum, other gases constituting impurities. They cannot, however, be described as oil, and therefore do not come within our present purview, any more than do the solid paraffins and asphalts, which, within the region under consideration, occur only as mineralogical curiosities. They are occasionally mentioned in this paper, as bearing upon their possible accompaniment by fluid oil, of which they may be the external, desiccated residue, left by oxidation or evaporation of volatile constituents.

Couleur de rose is so pleasing a tint that every optimistic prophet, no matter what his disqualifications for that function, is sure to be welcomed with open arms, his annunciations accepted as inspired, and his advice implicitly followed. On the other hand, the promulgator of unpromising views, however well based, must anticipate encounter with severe criticism, if not with direct obloquy and contumelious disparagement. In this respect human nature seems to have changed but little from the days of Isaiah and Micah, when "smooth things, deceits," were desired from the prophets, hatred and persecution being the meed accorded to unpalatable utterances.

It may have been already surmised from this prelude, that the writer is opposed to the widespread conception of a store of petroleum of commercial value lying intact within the limits of the British Islands. The natural tendency to accord belief to views of pleasing prospect accounts in a very large measure for the ready acceptance of this wholly untenable idea, and for the consequent outbreak of "oil-fever," although occurring in much milder form than has been the case in some previous epidemics of kindred nature in this country. Possibly the present stressful condition of existence has acted as a counter-irritant, abating the normal virulence of speculative meningitis. Should the diagnosis prove to be incorrect, and the symptoms really those of healthy development, no one will be more gratified than the physician, to find his sinister prognostications mistaken.

But pending such enlightenment, treatment for the disease indicated must be conducted on lines innocuous in either result, and the best system for adoption appears to be the injection of the antitoxin of facts, conveyed in a menstruum of sound reasoning.

The facts should be of at least "commercial" purity; that is, accurate in respect of important details. Errors, for example, as to the quantity of oil exuding at any place, by confusion of pints with quarts or gallons, or in the time in which such quantity was obtained, of hours, days, or even weeks, are generally trivial, in view of the insignificance of the entire discharge, apart from the

considerations of the effect of changes in temperature on the viscosity of the emanation, and of the relative position of the outlet, a drip from the roof of a colliery level being of necessity faster, *cæteris paribus*, than a rise from its floor. On the other hand, the representation, as a natural flow, of leakage of refined oil from storage is a grave deviation from verity, not necessarily intentional (any more than the leakage), but as reprehensible in respect of carelessness in the investigator as in the storekeeper who permitted the waste. The denunciations, as an opponent of the development of national resources, which were showered upon the devoted head of Prof. G. A. J. Cole in 1903 for demonstrating that the oil-spring in a Dublin cellar was of this unnatural character, should justly have fallen upon those who proclaimed the untested issue as prophetic of crowded derricks in Sackville Street, and the Liffey darkened with crude oil. These hyper-enthusiasts saw, in a slight undulation of the surface, the evidence of anticlinal or dome structure, so essential an element in reports of new oilfields that are going to supply the world when Baku is forgotten.

It may be remarked, by the way, that the parallel is always with Baku, a secondary reference to one or other of the American oilfields being but occasionally made. The mention of Baku generally gauges the recorder's knowledge of the subject. In a report once submitted to the writer, a genus of fossils, without identification of species, was mentioned as occurring in the new (supposed) field, as well as at Baku—a genus ranging from at least Devonian times to the present epoch. A yet more striking analogy was advanced between the Peruvian and Pennsylvanian oilfields, that both had 8 in. thickness of sand at the surface. It is to be hoped that a like reason for anticipating spouters will not be advanced for every British parish that can show an equal bed of sand, for both our past presidents would require 48 hours a day to deal with the resulting correspondence.

Expectations equally unwarranted by facts are fostered by headlines in the press such as "No doubt but it (oil) can be got," even if qualified in the following letterpress by the remark, "In what quantity no cautious man would venture to prophesy." The public grasp the headline, and ignore the latent modification.

Nature seems at all times, at least since the initiation of organic life, and possibly, but not probably, at earlier stages of the history of our planet, to have evolved, in nearly every part of the world, a wide range of hydrocarbons, in very variable quantity, sometimes for rapid dissipation, sometimes for prolonged storage. Without trespassing into the realm of teleological speculation, it

may be submitted that at least one beneficial result of this all but universal activity has been to foster the study of geology in regions where no other economic mineral occurs to tempt investigation.

There seems also to be a wide vertical range of the production, from the surface downwards, and the processes may have been as varied as the original material and the resulting mixture of oils of very different composition.

There is no reason, on the basis of the vast array of facts on record, to suppose that any but a minute proportion is due to purely inorganic reactions, under conditions practically beyond our power to reproduce, even were we in possession of precise knowledge about them. We have been able to produce a large number of organic compounds from purely inorganic material; but our processes are not such as are conceivable in Nature, nor do the materials occur naturally in the degree of purity essential to our methods. In short, we laboriously effect a mere approximation to natural products in a wholly unnatural way.

The natural storage of organic matter is demonstrated in the case of coal and peat, and, therefore, presumably the kindred carbon-compounds have a somewhat similar source. Gratuitous assumption that the latter have been chemically evolved from inorganic material, save to the most trivial extent, under exceptional and scarcely imaginable conditions, is as irrational an idea, in its chemical and geological aspects, as was the Ptolemaic astronomy.

A Spanish king, studying the latter clumsy conception, is said to have remarked that, had he been consulted, he could have devised a better scheme for lighting the earth—then the sole apparent purpose of the celestial system. The supply of fluid hydrocarbons by casual evolution from inorganic sources, and capricious accumulation in reservoirs discoverable only by wild-cat operations, is assuredly a still more clumsy conception than was presented in Ptolemy's charts of the apparently erratic movements of the heavenly bodies. His facts were fairly correct, but he had not secured the key to their explanation in the rotation of the earth and other planets. We have not yet discovered the key to the natural formation of petroleum from organic matter, but to turn, on this account, to vague conceptions of the hypothetical evolution of hydrocarbon compounds in volcanic centres (where they would be instantly dissociated), of their transmission alike through pervious and impervious strata, and their ultimate storage in places less favourable in many cases than those previously traversed, violates all laws of probability and deduction from observable facts.

Only, therefore, where the occurrence of hydrocarbons bears no conceivable relation to organic compounds, in meteorites for instance, are we justified in assigning to such an inorganic origin.

The graphitic material occurring in the veins of many goldfields—Mysore, West Australia, Victoria, Transvaal, Guinea and Brazil—retains a trace of hydrocarbon oil, precluding treatment for solution of the gold till removed by roasting. Here is, at first sight an inorganic hydrocarbon. But it occurs in quantity, as a common veinstone, and in all cases the "country rock" which these veins traverse is a metamorphosed sedimentary deposit. Where this is a graphitic gneiss, the carbonaceous matter tends to segregate into veinlets and lenticles. In short, these regions present us with lost oilfields,* metamorphic action having largely coked the petroleum for lack of attention to temperature, whilst a mere trace remains of a compound of undetermined nature except its greasiness. The permanent gases have of course escaped, or are biding their time in some crevice not yet reached in mining. Presumably like action has occurred wherever graphite is found, and where simple hydrocarbon gas is discharged in mines through metamorphic rock, as in Cornwall and Wales, it is probably the result of a similar process, the decomposition of some form of organic matter in the deep-seated rocks beyond the ken of the miner's pick.

Turning from these generalities to specific instances within the area of the British Islands, and restricting attention to actual petroleum, however tarry its condition, we find the earliest in geological sequence is the viscous tar, often consolidated into albertite, occurring in the lower Old Red Sandstone of Dingwall, and sometimes descending into crevices in the subjacent gneiss. Petroleum is vaguely reported on the Orkney mainland, which consists of the middle division of the same series. As this has, in Caithness, sandstones cemented by bituminous matter, and on the island of Hoy veins of albertite, the conditions of deposit were evidently such as to favour the formation of hydrocarbons, some of which may have remained fluid. At Cupar, in Fife, basalt veins traversing the upper part of the series have collected, into the intercrystalline and other spaces left by contraction in cooling, enough benzine to show wetness for a brief interval on freshly-broken surfaces. But slightly newer than these instances was the vein impregnated with mineral oil, exposed in 1874 in the foundations of a factory in Barnstaple, traversing Upper Devonian shales. An oily substance, but not of

* Where part of the country rock is limestone, this is almost invariably dolomitic, or, in more advanced metamorphism, serpentine—a further analogy with unaltered oilfields.

mineral origin, was many years ago found in the Torquay district, and proved to be an exudation from bat-guano. The surrounding rock, in this case, was of Devonian age, but the bats were somewhat more recent. The alleged occurrence of traces of oil in a boring at Willesden in the Upper Devonian shales is perhaps hardly more worth mention than the bat-grease.

In the succeeding Carboniferous series the occurrences of hydrocarbon fluids are much more frequent, not so much, perhaps, from conditions of formation, though the fauna and flora are more frequently well preserved, if not more copious, as from the extensive mining operations, which have revealed pockets of oil where none is seen at the surface.

In the lowest member of the series, the Calciferous Sandstone group, occur the oil shales, so extensively worked in the Lothians. From amongst these shales petroleum appeared at Broxburn in 1866, some 200 barrels being obtained. This Mr. Cunningham Craig regards as oil which has escaped the process of conversion into kerogen, but the following passage from the Geological Survey Memoir on the Oil Shales of the Lothians (Ed. ii, 1912, p. 15) points rather to its being the product of natural distillation by the heat of intruded igneous rock. "Cases are known (e.g. the Nether Dechmount boring near Livingston, the Wyndford bore at Binny, or No. 94 bore, Pumpherston) where 300 feet or more of strata have been pierced, all of which are badly burnt, the oil-shales completely destroyed, and the strata reeking with oil, although there are only occasional sills of dolerite, a few inches thick, throughout the section. In another boring (No. 418) by James Ross & Co., south of Philpstoun, the plant-remains in the blaes beds were all carbonised, and the oil-shale positions useless, for over 150 ft. above a dolerite sill, whose thickness was not proved." Other instances of the occurrence of petroleum in the region, definitely associated with intrusions of igneous rock, are mentioned on p. 168.

On the other hand, a different explanation is suggested, on p. 89, for a case in which no such intrusions are known. In the Newyearfield boring near Livingston, the Pumpherston shale, and another band about 140 ft. below it, were found altered into dark blue shales, smelling strongly of petroleum, as did all the intervening and lower strata, though no sign of intrusive rock was perceptible. But between the two destroyed oil-shales is a considerable thickness of contemporaneous volcanic ash, with much pyrites and bituminous matter. It is suggested that, during periods of desiccation, alternating with those of deposition, oxidation of the pyrites

evolved sufficient heat to break up the kerogen in the shales above and below, evolving the petroleum without actual combustion: evidence of such desiccation is mentioned as occurring at two horizons in the Pumpherston shale. A fatal objection to this explanation is that the pyritous ash was covered by at least 60 ft. of deposits before the Pumpherston shale even began to exist. Oxidation through such a thickness is difficult to imagine, and its evolution of sufficient heat to distil the oil-shale 20 ft. below is still more so, whilst one would think that the deposition of the 50 ft. of the Pumpherston shale, even with intervals of desiccation, would reduce the temperature to below that requisite for distillation.

As bearing upon this question of transmission of heat, it may be mentioned that a basalt sill at West Calder, 261 ft. thick, has burnt the subjacent beds for only 6 ft., a good oil-shale lying 10 ft. lower. At Broxburn, a 5 ft. sill has had no effect on the oil-shale 8 ft. below it, and a sill over 10 ft. thick, whilst destroying a shale 6 ft. above it, had no action upon another 8 ft. higher—save that the latter has veins of albertite penetrating it, probably from the lower destroyed seam.

The analysis given in the memoir cited may be reproduced here: (*a*) the Broxburn oil of 1866; (*b*) oil occurring in cavities in the last mentioned sill 16 ft. below the Dunnet shale; (*c*) crude shale oil of the Broxburn Oil Company's Albyn Works:

	a.		*b.*		*c.*
	s.g.	%	s.g.	%	%
Naphtha	·700	5·0	·740	4·5	3·5
,, ...	·730	5·2	—	—	—
Burning oil	·802	34·1	·810	36·1	32·0
Intermediate oil ...	·840	10·5	—	—	—
Gas oil	—	—	·840	—	4·0
Lubricating oil ...	·865	16·7	·865	6·6	6·0
,, ,, ...	—	—	·885	19·0	18·0
Paraffin.....	—	12·5	—	8·8	11·0
Loss in refining ...	—	16·0	—	25·0	25·5
Specific gravity ...	·830		·866		·868
Setting point	61° F.		65° F.		88° F.
,, ,, of paraffin	103° F.		106° F.		115° F.
Bromine absorption in burning oil ...	6·5 %		8 %		41 %

The figures may suggest some alternative hypothesis in explanation of the phenomena involved. There are, however, more reactions

within the earth than are dreamt of in the philosophy of pyrogenesis. The oil-shales, like the coal seams, evolve abundant hydrocarbon gas devoid of odour, and where the water that originally sealed this from escape has been drawn away by mining the shale, the gas issues along the outcrop of the beds, making barren belts across the arable land, and evolving sulphurous odours by reacting with sulphur compounds in the soil, which along these belts has a temperature 40° F. higher than that in the immediate vicinity.

The films of oil that have long since been noticed on the surface of the water of St. Catherine's Well, Liberton, some four miles south of Edinburgh, come from about the same horizon as the Dunnet Shale, and the Binny Sandstone at Straiton, a mile farther south, is too much charged with oil to be used as a building stone. In neither instance are there known or suspected igneous rocks of Carboniferous or later origin, but the beds are intensely crushed against the resistant mass of the Pentland Hills, volcanic rocks of the Old Red Sandstone period, and heat may have been developed by friction to sufficient extent to break up kerogen into petroleum.

Passing to the next subdivision of the Carboniferous series, the Mountain Limestone, we find in Derbyshire many cases of hydrocarbons of much scientific, though no economic, interest. Of these, most attention has been given to the elaterite or mineral india-rubber, of Windy Knoll, Castleton. This exudes on the top of a low knoll of limestone, a few feet from the edge of a quarry, in which no trace of it appears. It flows after rains in summer as a bright yellow tar, rapidly changing through various reddish tints to a light brown, whilst its texture is correspondingly modified to the elasticity which the names connote, and finally to a brittle condition. The names being appropriate only to an altered state arising from desiccation and oxidation, the mineral requires a new title. Its capricious mode of exit shows how futile it would be to search for it by boring, were it worth its weight in gold when obtained.

Asphalt, liquid petroleum and gaseous hydrocarbons are frequently recorded in accounts of the old lead mines about Castleton, Eyam, Stony Middleton, Ashford, Youlgreave, Winster, Ashover and Wirksworth, but their occurrence in veins leaves their original position in doubt. Sheets of igneous rock (toadstone) are generally present in such cases, whereas there is no record of hydrocarbons in the Yorkshire mines, in limestone of the same age, but devoid of igneous intrusions. In the Derbyshire region hot springs indicate the continuance of chemical action, and would facilitate the migration of viscid hydrocarbons along the channels offered by

veins. On the other hand, gas occurs in the hæmatite mines of Cleator Moor, Cumberland, and, accompanied by bitumen, in the Flintshire lead mines, and traces of oil are said to have been noticed in the Anglesey limestone.

From the upper part of the Carboniferous Limestone at Ashwick Court near Shepton Mallet, and from two other points within two miles from it, was obtained the remarkable oil mentioned, with the dramatic details of its discovery, at our meeting of last January. The occurrence is mysterious, partly from the character of the oil, resembling in some respects a refined product, partly from the increase in flow associated with the earthquake of 1892 (though it had been noticed in the previous year), and partly from the extensive exposure of a vast thickness of beds above and below in the immediate vicinity, rising to the surface at high angles, and devoid of any similar indications.

The next division of the Carboniferous system is constituted by the Yoredale Beds, alternations of limestones, sandstones and shales. From these in 1889, in a boring at Norton, near Stockton-on-Tees, black oil rose continuously after a thickness of about 750 ft. of Triassic and Permian beds had been penetrated. Paraffin wax was found in 1905 in a drift cut through the Yoredales in Ladysmith colliery, Whitehaven, Cumberland.

The next division in geological sequence is the Millstone Grit, which yields the unique flow of oil from the Kelham boring near Newark. The series is only 240 ft. thick, with the oil sand about 80 ft. below the base of the Coal measures. We cannot in this case indict Pluto as the perpetrator of mischief, as the only igneous rock is a dolerite sill more than 1,300 ft. higher in the series. The sill had, of course, its source far below, but the site of the feeding "neck" may be miles away from the boring. So we must for the present assume the oil to be indigenous to the rock in which it occurs, and perhaps we shall some day attain to fuller knowledge on the subject. The sand, however, is but 16 ft. thick, and it is very doubtful if prolongation of the boring (which stopped at 19 ft. deep in the Carboniferous Limestone) would have reached any deeper source of oil.

In the Coal measures, natural and artificial emanations of hydrocarbon gas are abundant. Not only are such developed in the course of mining operations, but there can be little doubt that these, by disturbing the equilibrium of opposing pressures, tend to set free from the faces of coal, or from fissures extending into the seams, large volumes of combustible gases, that would otherwise have remained sealed up in the coal. Natural gas-springs, prior

to mining operations, are recorded at but few points, Wigan and Broseley being classical instances, mentioned in the literature of the 16th and 17th centuries, but now, besides the vast efflux of gas from mines, very partially utilised, there is doubtless a much greater bulk set free by fissures due to subsidence in the worked-out areas, an escape not less real because so diffused as to be imperceptible.

Fluid petroleum is on record in several coal-mines, sometimes oozing from faults, more frequently dripping from the roof of the coal. Too often the record, whilst meticulously, if not mendaciously, detailed in respect of trivialities of time and quantity of the emanation, merely mentions the district, and not the mine, the seam, or other position, and from the results of laboratory examination, in like manner, are omitted essentials as to process adopted, much reducing the value of the figures given. It is not proposed upon the present occasion to go into such details of quantity or quality. Necessarily a drip from the roof of a coal seam, under which ways have to be kept open, is more permanently noticeable as well as more rapid, than an oozing from the face of a fault or other surface passed in a gallery, to be speedily hidden by walling or brattice, and forgotten.

It must further be borne in mind that the roof of a coal seam *ipso facto* implies a change of conditions, from terrestrial vegetation to subaqueous deposit of sediment, and this was in not a few cases brought about by subsidence, the sea often invading an area previously supporting terrestrial growth. In the Staffordshire coalfield many such marine invasions have been detected, and several in Derbyshire and Nottinghamshire. The coeval deposits of Yorkshire and Lancashire would doubtless furnish similar evidence if fully studied in this respect.

If petroleum is principally due to marine organisms, either vegetal, animal, or of the neutral character at the bottom of either scale, such invasion furnishes at once a wider area for occupation, and abundance of dead vegetation as nutriment. Consequently, the roof of a coal seam is a watery paradise for the development of oil-making organisms, and if the deposited sands or clays are of suitable character for storage and cover, there is a chance for the formation of oil.

The following is a list of occurrences of oil in coal mines, as far as seem to have been recorded, but in many cases essential data are omitted, whilst trivial details are superabundant:—

Cumberland.—Whitehaven, Ladysmith pit.

Yorkshire.—At Manvers Main colliery, Wath-upon-Dearne, gas

and oil were noticed exuding from the roof of the Parkgate seam. A mass of paraffin wax was met with in the shaft 250 ft. above that seam. At Hemsworth, oil dripped from the roof of the Haigh Moor seam, 300 ft. above the Parkgate. Oil is reported to have been observed at Dinnington colliery, but the writer has not learnt the depth, nor the horizon at which it occurred, the published section not mentioning petroleum.

Derbyshire.—In the Riddings colliery, oil flowed, and was used as a lubricant for some years, coming from the roof of the Kilburn seam, the deepest of the valuable seams in the field. Its roof rock contains abundant remains of fish. The reports of oil at Butterley and Ilkeston probably refer to similar associations with the Kilburn seam. At the Southgate colliery, Clowne, a considerable flow of oil occurs from strata accompanying the High Hazles coal, about 1,630 ft. above the Kilburn, and 400 ft. above the Haigh Moor, whilst the Top Hard coal, the best and most extensively worked throughout the field, and nowhere exhibiting a trace of oil, lies about 240 ft. below the High Hazles.

Lancashire.—The situation of the historic gas jet at Wigan is very vaguely indicated as a mile and a half or two miles from the town, no direction being stated. In the Wigan Iron & Coal Co.'s Sovereign Pit No. 3, sunk to the Arley seam, oil oozed from the floor at a fault. Oil is reported at West Leigh, Hulton, Worsley and Newtown, near Swinton. In the last case, and possibly in the others, the Cannel seam is the source.

Staffordshire.—Oil exudes from the floor of the Bullhurst coal in Fairlady pit, Leycett, and from the roof of the Cockshead seam in the Longton district, some 200 ft. higher in the series. It also saturated the measures in connection with the Bowling Alley coal, 640 ft. above the Cockshead, at Meirhay colliery, Longton. This for five years yielded about five tons of refined oil per week, produced at a small refinery at Cobridge, near Hanley. Marine fossils occur in the roof of the Bullhurst seam and in the beds below it, indicating frequent alternations of marine with terrestrial conditions. The Cockshead and Bowling Alley seams have no marine associations, but the beds above and below them have abundant remains of fish and freshwater mollusca.

Shropshire.—Springs of tarry bitumen have long been known at Coalport on the Severn, and Pitchford, eleven miles thence to W. by N. These are situated at the junction of the Coal measures with the older slaty rocks that hereabouts form their immediate substratum. That bitumen occurs in these older rocks at rare intervals is simply explained by the former extension of the Coal

measures over areas now denuded of them. Instances are on record at Haughmond Hill, east of Shrewsbury, and Nills Hill, Pontesbury, southwestward; the veins of ore in the Snailbeach mine, Minsterley, and the Bog mine, Shelve, probably owe their traces of bitumen to a like source. Higher in the measures, the sandstones are frequently charged with petroleum at Coalbrookdale, Madeley, Priorslee and Wellington.

In the other coalfields there seems to be no occurrence of oil, tar, or asphalt.

In the Permian series, a boring at Seaton Carew, Durham, had traces of oil, and the water of wells at Ruabon, Denbighshire, has been contaminated by similar exudations. The character of the rock, though of the same geological series, is wholly different in the two cases—red marls at Ruabon, magnesian limestone in Durham.

In the Triassic salt beds of Cheshire emanations of gas are not infrequent; traces of oil occurred at Anderton, near Northwich, and the asphalt at Bearwood Hill, near Burton-on-Trent, is in rock of the same period.

In the Continental Permian and Triassic series, a similar association of salt and petroleum is usual, whilst the Rumanian, Pennsylvanian and Texan fields and the Dead Sea region illustrate the same connection (obscure though the chemical relation may be) as obtaining at widely-separated epochs—Devonian, Cretaceous and Tertiary.

In the Liassic series, traces of oil have been found in two or three places in Somersetshire and Cleveland, the clays in both regions being richly fossiliferous. A reported case at Husband's Bosworth, Leicestershire, in 1906, proved to be an escape of refined oil. A boring at Calvert, Bucks, gave off a blower of gas from the Liassic clay, which, by the way, was just there of an exceptional colour, red, much like the Triassic clays.

The Jurassic clays are frequently charged with bituminous matter, reducing the amount of fuel requisite for brick-burning, and free oil is reported in them at many points by Dr. Forbes-Leslie, besides shales capable of rich yield by distillation. The gas discharged from the Purbeck beds, at Heathfield, and other places in Sussex and Kent, has been hastily assumed to be indicative of subjacent stores of petroleum, but the only direct evidence was that parts of the Kimmeridge clay in the Battle borings were wet with oil, which, nevertheless, did not flow into the borehole, a sufficient condemnation of the series as a source of oil for commercial purposes.

Except for an alleged escape of gas from the lower chalk at Bassingbourn, Cambridgeshire, the Cretaceous and Tertiary beds, rich yielders of petroleum in other parts of the world, are in England devoid of any trace of hydrocarbons.

The Post-Tertiary epoch is rarely credited with economic minerals indigenous to the deposits, yet the oil in the peat of Down Holland moss, near Formby, in Lancashire, and in several of the extensive Irish bogs, is a true native petroleum, and though dispersed through an earthy medium may be extracted therefrom with little or no alteration, whilst the remainder of the mass may, by continuing the operation at increased temperature, be broken up into a variety of useful hydrocarbons. The chief drawback to the extensive use of this abundant substance is its saturation by water, but that is not necessarily an insuperable obstacle. Still, the need of a distillatory process removes peat, however charged with oil, from the category of matters contemplated as the subject of this paper. Sand and water, mingled with oil to whatever extent, will largely settle out; clay and peat will not do so; the semi-combination involved precluding the hydrocarbon from being considered free.

Besides abundant exposure at the surface, the British geological series has for centuries been subjected to penetration by mines and borings practically throughout its thickness, and no extensive area has escaped the test of drill or pick. The results, as far as petroleum is concerned, have been summarised above.

Further operations, conducted with increased attention to minutiæ too often ignored, will establish more precisely the position of concealed boundary lines, where, as in Kent and Yorkshire, for instance, the Coal measures and older rocks present a complex of various series as an irregularly-worn floor, on which rests, independently of pre-existent tectonic structure, a wide variety of Secondary deposits, each member of which has, in consequence of repeated movements and erosions, its own variations in thickness and its own marginal limitations. Such data are of more value in respect of water supply and coal than of the petroleum of which they usually indicate the absence.

It is much to be doubted whether in any part of these Secondary rocks or of the subjacent Palæozoic series there exists any deposit of petroleum of a commercial value commensurate with the cost of wild-cat search (for such it must needs be) and subsequent exploitation. Yet the Kelham and Norton instances demonstrate the possible occurrence of oil in deep-seated portions of series of which the wide areas of outcrop yield no similar indications. In view of our ignorance of the tectonic structure obtaining in these older

rocks to the eastward of proven points, the term wild-cat is not too strong; for, although the overlying rocks indicate various tectonic movements — presumably influenced in depth by pre-existing structure—we do not know the degree of that influence, still less the extent to which the older rocks have been brought within reach of denuding agencies to form the floor on which rest the newer rocks; an anticline in the Secondaries may be "post-humously" along one of older date—it may be oblique or directly transverse to flexures that would control the accumulation of Palæozoic oil, if such exists.

It is demonstrated, then, that in the British Isles—as in other parts of the world—oil-forming conditions have frequently recurred, but to a very limited extent; and although conditions favouring its accumulation, and tectonic structures capable of conserving it from escape, are also of frequent occurrence, the conjunction of the latter essentials with original formation has generally failed. Our reservoir rocks are full of water, demonstrating the absence of liquid hydrocarbons. The curves of our anticlines and synclines serve to enhance the beauty of our landscapes, and their formation has, under favourable conditions, resulted in ore-bearing veins, but to reduce that ore, as generally for heat, illumination and motive-power, we must continue to depend upon solid minerals of native source, and fluid combustibles imported from abroad.

The feeble and short-lived flows which our rocks exhibit necessarily conform to the same hydrostatic laws as the vast bulks of other regions, but whether from defect of original formation, of space accessible for accumulation, or of adequate seal from escape, the total result is, from a practical commercial point of view, valueless, except possibly in the one or two cases mentioned above. To geologists, negative evidence in respect of petroleum would be accompanied by so much of interest and value in other directions hat their trivial share in the cost would be gladly borne, but owners who looked for royalties would be less complacent under their disappointment. Hope is more easily excited than regrets consoled. It is scarcely necessary to say that the drill and pump constitute the final Court of Appeal, but the charge of hoarding petroleum is not at all likely to be substantiated.

DISCUSSION.

The President remarked that all had listened with very great interest to the views expressed by Mr. Dalton as to whether oil could or could not be found in commercial quantities in the British

Isles. If doctors differed in such a marked degree on a matter of such vital importance to the country, it was clear that opinions would not suffice, and that the question must be settled in the only conclusive way, i.e. by testing all parts of the country with the drill. It would be a matter of great interest to hear the views of other geologists on this important question, and he hoped that Mr. Dalton's paper would prove productive of a useful discussion; and in the first place he would call upon Mr. Cunningham Craig to give his views.

Mr. E. H. Cunningham Craig regarded Mr. Dalton's paper as a most timely one, and he thought the Institution was to be congratulated on the fact that a geologist of such great experience and power of expression should have given such a paper at the present time. There was no doubt that since the Bill dealing with drilling for petroleum in this country had been introduced into the House of Commons, considerable excitement with regard to the oil prospects had flowed over the country like a wave, and he feared that people expected oilfields to be discovered in all parts. Of course those who had studied the question as closely as Mr. Dalton knew very well that the chances of finding liquid petroleum in anything like a commercial quantity in this country were few and far between.

Before, however, dealing with that aspect of the question the speaker desired to make one or two references to the evidence from Scotland which Mr. Dalton had adduced. He had instanced the finding of petroleum in a sandstone at Broxburn, which the speaker had claimed, in a paper read before the Institution, as probably a free petroleum, a true crude petroleum, and not a naturally-distilled oil. The reasons that had determined that opinion in the matter were the following:—(1) the flow of petroleum was greater than was usually obtained from naturally distilled oil; (2) the oil was accompanied by brine; (3) there was no igneous rock in the near neighbourhood; (4) the oil had a green fluorescence, which he believed was either unknown or very rare in the case of naturally-distilled petroleum; and (5) analysis proved that the oil was entirely different from the naturally-distilled petroleum so well known in many parts of Scotland. Many of the borings in the Newyearfield had passed through "burnt shale." The Scottish shale miners knew well that when they found a seam of oil-shale close up against a large igneous intrusion that the oil was distilled out of the shale, the shale being said to be "burnt." But even when they encountered the geological horizon of the oil-shale, and found the material poor, and hardly

oil-shale in any sense of the words, they still called it "burnt," notwithstanding that they could not show any sign of igneous intrusion in the neighbourhood. In relation to some of the borings near the Newyearfield, mention had been made of various sills of igneous rock. In the boring-journals various small thicknesses of strata were entered as "whin," i.e. intrusive igneous rock. Many of these had proved to be thin bands of hard calcareous sandstone. So that in some cases it was very difficult to assume that there had been any natural distillation by igneous rock. Again, at St. Catherine's Well the strata were very sharply folded and faulted against rocks of Old Red Sandstone Age; but there was no crushing of the strata as Mr. Dalton had suggested, and certainly there was no reason to believe that there could have been heat enough developed by crushing to distil the oil from the shales. The well was in folded strata, on the flank of a minor anticline, and the oil was believed to be a true crude petroleum.

Returning to the main point of the paper, the speaker found it rather difficult to understand on what grounds Mr. Dalton was inclined to condemn the chances of finding oil in paying quantity in this country. The author had only mentioned one or two of the localities where there was any likelihood of bores being put down. Had Mr. Dalton taken into consideration places where it was known that the structure was good, and there was some reason to believe that crude petroleum might be beneath the ground, and had shown in such cases why oil could not be there, greater weight would have been attached to what he said. To put the case in a nutshell, after the deposit of the Coal measures, earth-movements formed a great series of anticlines and synclines; the anticlines had been denuded off, and only the great synclines were left. At that time there may have been oilfields, but they had been destroyed by denudation. But even in the synclines minor anticlinal structures were found in some places, and it was to these that prospectors were looking with interest to-day.

It was quite certain that at one time there had been oil rocks in this country. The great sandstones at the base of the Calciferous sandstones in Scotland, and the two sandstones rather farther up, the Binny and the Dunnet, had, at one time and in certain places, been oil-bearing rocks; and they sometimes still showed traces of it. The danger was not, however, that the oil might have been entirely dissipated along faults, but that in the course of time the lighter oils might have been dissipated, and the heavier oils absorbed, leaving only certain heavy residues and a certain amount of natural gas. In Queensland, where very deep borings

had been made, there had been found, at a depth of 5,400 ft., a very heavy inspissated oil, solid at ordinary temperatures. A specimen of that oil had been sent to the speaker by the Government geologist of Queensland, Mr. Cameron. This, possibly, was the kind of thing that might be expected here, and, were that all that was to be found, the oilfields of Great Britain would be a failure. The real question, therefore, was whether our oilfields were "has beens," or what the Americans called "never wasers"; or whether there was a possibility that there might be some left in certain places.

Transferring to the country, instead of the public, Mr. Dalton's metaphor of medical diagnosis, it might be said that Mr. Dalton had diagnosed the patient in the case as already dead and, it might even be said, decomposed. But there were other practitioners who held that there might still be a spark of life left. It might be neither a long nor a happy life, but those practitioners were determined that if there was any chance of life at all it should be fostered in every possible way. In the hope of preserving that life, and on the chance of finding that it still existed, the practitioners proposed to operate.

Dr. W. Forbes-Leslie desired to refer to the excellence of the speech just made by Mr. Cunningham Craig, and to add his own congratulations to the compliments paid to the author by Mr. Craig. He particularly appreciated the paper because it focussed the whole subject, giving the negative side of it in a way which the speaker had been unable to achieve when presenting the positive side of the argument to the Institution some months ago. There could only be true form and proportion when both sides of a question had been discussed, and for that reason he welcomed Mr. Dalton's paper as a very valuable contribution. At the same time, there were certain features of the paper which required discussion.

He was unable to go as deeply into the question of the Scotch shales as Mr. Cunningham Craig; but he thought the fact that there were so many occurrences of oil in this country was a matter that should be borne in mind. To attribute all the appearance of oil in this country to local conditions, was, it seemed to him, to ignore their frequency and distribution, which imply a very general distribution of oil, either in the Carboniferous, the Pre-Carboniferous, or the Secondary formations.

The speaker had been carrying out some petroleum drilling in Norfolk since he had last had the pleasure of speaking to the Institution about that region, and, in the case of several interesting occurrences in the Jurassic series, he found that, below the

bituminous series there were jointed clays, and in the joints of these clays there was free oil. This was a very interesting occurrence. It might, of course, mean that there were sills or igneous intrusions deeper in than the series, though such had not been found up to the present time; on the other hand, it might be due to oil in quantity lying below or in the Jurassic series, or to some other unexplained cause: whatever it was, the oil was there.

Mr. Dalton had stated that the rocks of England had been so thoroughly tested, by drill, pick and other means, as to prove them practically devoid of oil in any economical quantities. Dr. Forbes-Leslie did not think that statement correct. The Palæozoics of England might have been tested at their exposures in certain districts, but there were districts in which the drill had not penetrated to that system, particularly in the east of England. The tectonic structure of these deep-seated deposits had, of course, an important bearing on the subject. It was to be hoped that some places might have, beneath the Secondary cover, favourable structure for the accumulation of oil, similarly to the exposed Palæozoic areas, and that such would be indicated in some measure by their influence upon later movements during the Secondary and Tertiary periods.

He thought that Mr. Cunningham Craig had rightly come to the conclusion that as yet there was no knowledge of what existed in England in the way of oilfields. It was, however, known that we had had oilfields, and that those oilfields had been dissipated; but it was at present unknown whether we had any left. Nevertheless, there were many suspicious indications which in our colonies and other parts of the world would have drawn capital for development. These symptoms, hitherto overlooked, made a very good case for asking the Government to supply funds for testing what might exist in certain parts of England which had so far lain untested. It was highly probable that in the event of petroleum not being obtainable, something valuable might be found, and he did not think that money spent in certain areas in the east of England would be thrown away. In conclusion, he wished to thank Mr. Dalton for his very interesting paper and for putting the subject on such a plane that the proportions could be duly weighed and observed, and the "oil fever" which Mr. Dalton was afraid the country was falling into might be cured.

Mr. J. Ford, C.E. (visitor), rose to add his testimony to the academical excellence of Mr. Dalton's paper, but was disappointed that so much of the paper was occupied with the discouragement of research rather than suggestions or help as to the prospect of finding

oil in this country, as was suggested by the title. Mr. Dalton had stated that the country had been pretty well tested by colliery shafts or borings, without finding much indication of oil; but, as a matter of fact, the horizon at which oil might be expected to be found—the lower part of the Millstone Grit, in which Mr. Dalton had admitted, in the case of Kelham, that the oil might be indigenous to the rock—had never yet been reached except in that one place. None of the eastern side of the Trent had ever yet been touched by the drill, while the western side had been only very partially tested—the Kelham boring was the only one which had yet pierced the Millstone Grit series—and he could see no reason why that oil-containing rock should not prove of considerable extent. Mr. Dalton had no expectation that any further boring in the limestone would lead to oil being found below, but the speaker could see no reason for doubting that probability, and he would like to have from Mr. Dalton an expression of the grounds of that adverse conclusion.

The speaker deduced from the paper that free liquid oil, indigenous to its containing rock, had been found in certain parts of the country. Indeed, that part of the paper containing this information appeared to him to be the best, as, having discovered that such oil existed in the country, the decision as to the probability of further supplies must be left to the drill. Speaking as a mining engineer of some experience, he had no doubt that the whole of the lower valley of the Trent was a field in which oil might be expected to be found, one which up to the present had never been touched by the drill beyond the Middle Coal measures; while, as he had said, the western side was only partially touched. There was therefore a large field worthy of more research and proof by the drill. Further, he would ask why the British Isles should not be as richly blessed with Nature's gifts as any other part of the world. Oil was admittedly found in Baku, Russia, in Rumania, etc., why not in England? Why was this exception made? It remained for the drill to prove the ground which had so far never been tested. He was very pleased to have been present, and heard Mr. Dalton's paper, and to add his tribute to its excellence to that of others.

Mr. George Barrow (H.M. Geol. Survey, visitor) considered that a great debt of gratitude was due to any man who had the courage to come forward and throw cold water on one of those epidemics by which the British public seemed to be periodically attacked; apparently, the British public liked being humbugged. It had been suggested that there might be a great deal of oil near certain areas, but the answer was that we must be guided by the

results obtained in areas already explored, where the possibility of finding any oil of commercial value has been disproved. Had the American Government wished to know the chances of getting oil from any part of America, they would have gone to the proper authorities to make their enquiry; namely, the United States Geological Survey, whose publications, he might remark, were the finest in the world. In this country the Geological Survey should have been asked to block out the areas over which it was quite certain from deep mining operations that there was no oil. When that was done, it would be found that the areas where there was any prospect of oil were very small indeed. There were a few districts where there might be some prospect of success, and Mr. Cunningham Craig had referred to the type of area which the speaker would like to see tested, but the sites were completely concealed by the Secondary cover. The reason why the oil had gone from this country was that the Carboniferous formations had been folded up into great anticlines on a very large scale, but these were eroded, soon after the Carboniferous epoch, and later on were covered by rocks which gave no clue as to the older underlying structure; the result was that most of the oil had escaped, if it was ever formed. There were areas of considerable size where the Coal measures were covered up by an enormous thickness (more than 2,000 ft.) of Carboniferous rocks of a clayey nature, preventing the escape of any oil which might be formed at the expense of the carbonaceous material. It was quite possible that there might be one or two sources of oil of the type that Mr. Cunningham Craig had referred to, good sites, if it were only possible to strike them. The scheme, however, was a "wild cat" scheme. How was knowledge to be obtained of the position of the local anticlines and synclines in the Coal measures? With regard to the eastern counties, the ground had been proved as far north as Yarmouth and Lowestoft, and there was no prospect of getting oil there; to go farther north was simply "wild catting." No one had any idea where to put down borings, save in one or two special cases. Had the Geological Survey been consulted in the matter, they could have suggested one of the most promising, but, personally, the speaker did not believe that there was any oil even there.

Sir Boverton Redwood regarded the paper as one of a characteristically thoughtful nature, and worthy of the high reputation of the author, who was well known to have had exceptional experience in the geology of petroleum. Incidentally, he would like to say a word of praise of the manner in which the paper had been read on the author's behalf. (Applause.)

He did not propose to attempt to discuss the paper in detail, because, in his opinion, it was one which merited, and, indeed, demanded, far more consideration than he had yet been able to give to it. He, however, desired most earnestly to express the hope that the paper would not lead to any discouragement of investigation; though, in view of certain extravagant statements which had been made, it was all to the good that such a masterly review of the character of the problem to be solved should have been presented to the Institution.

The real justification for the attention which was being given to the question of whether or not free petroleum existed in this country in payable quantities was the imperative need for rendering the nation independent, as far as possible, of imported supplies; and he regarded that justification as an ample one.

In that connection he might echo a remark that had been made by a previous speaker, and say that the part of Mr. Dalton's paper which he liked best was the conclusion, in which the author referred to the drill as the final arbiter.

All, of course, accepted that statement, and it was because it was the only method of ascertaining whether or not it was possible to make this country independent of imported supplies, that he (the speaker) maintained that the nation would be blameworthy if it did not put that test into effect. Unless such a test was applied, there would always be many who would say that the utilisation of a provision of nature which might be of the very greatest service in our need had been neglected.

There could be no doubt that much might be said on both sides of the question, and the speaker had listened, with the greatest interest, to the remarks which had fallen from Mr. Cunningham Craig and Dr. Forbes-Leslie in particular. After all, however, the fact remained that until the only conclusive test had been applied, it was impossible to do more than speculate upon conditions which were practically unknown.

Mr. V. C. Illing considered that Mr. Dalton was to be heartily congratulated on a most excellent paper. The author had put this subject of the oil prospects in England before the Institution in a better manner than any other communication with which the speaker was familiar, and had, moreover, brought a much-debated matter to a head, so that it could be publicly discussed. The author's reasoning had been directed to showing that though traces of oil occurred over the whole country, and it could be found in various places through most of the formations, particularly the Carboniferous, the actual quantities were never large. In this

characteristic England was by no means exceptional, for an examination of the geological formations in many other countries would show the same type of thing, i.e. small quantities of oil in all sorts of rocks, igneous as well as sedimentary.

What was still further needed, however, was a more extensive statement as to the geological structures in reference to the possibility of reservoirs being left uneroded between the formation of the oil and the present time. He believed that most people who had studied the question at all would admit that of all the geological systems in which oil might occur in Britain the most probable was the Carboniferous, particularly the beds overlying the principal limestones, in which a smell of petroleum was often perceptible. The vital question was whether or no any of that petroleum has escaped loss by leakage.

Consideration of the geological history of these islands since the Carboniferous period showed that throughout the Permian and Triassic periods most of the country was being denuded. That denudation was prolonged and extensive, cutting deeply into the anticlines, leaving Carboniferous beds, with rare exceptions, only in the synclinals. On the surface left after this strong erosion, the Triassic and, subsequently, Jurassic beds were laid down.

The remarks of some of the speakers seemed to imply that little or nothing was known about the formations underneath these Secondary deposits. More was known than was generally supposed, for in several localities bores had been carried through the Secondary deposits into the underlying Palæozoics. The bores at Calvert and Bletchley went down straight through the Secondary into the Cambrian in one case, and in the other into "granite" boulders, indicating the proximity of Archæan. Five or six borings in London had gone straight from the Cretaceous down into the Old Red Sandstone. At Lowestoft, at about 1,600 ft. below Ordnance Datum, the bore entered rocks which were certainly Pre-Carboniferous, and probably Silurian. In the borings at Harwich and its vicinity, at about 1,000 ft. below Ordnance Datum, beds were reached which were probably Silurian. In several places, therefore, fairly if sparsely distributed over the eastern counties, there were borings which had gone down to the Palæozoic. With the exception of the borings at Northampton (Kettering Road), and Gayton, all the lower rocks proved were Pre-Carboniferous.

So far as the present evidence went, it tends to indicate that under the Secondaries the spreads of Pre-Carboniferous formations are larger than those of the Carboniferous. If between and among these bores there were unproved patches of Carboniferous rocks,

these would be mainly synclinal. Even if we made liberal allowances for the size of these covered synclines, the subsidiary anticlines within the main basins, on which Mr. Cunningham Craig lays stress, would be of very small dimensions. While, therefore, the speaker would not dispute the probable existence within suitable structures of small relics of oil, he was opposed to the view which encouraged the expectation of extensive deposits.

But it might be asked why confine attention to the Carboniferous? Why not search the underlying formations down to the Archæan? The known occurrences of traces of oil in the Pre-Carboniferous rocks are much less common than in the Carboniferous, and in addition the same causes which militated against the possibility of oil being proved in the Carboniferous, reacted to a greater degree in the underlying formations. The Cambrian, Ordovician, Silurian and Devonian deposits had been affected in all by four cycles of movement in Pre-Carboniferous times, of which the fourth or Caledonian set of movements was one of the greatest in the geological history of Britain. The important bearing of these movements in the present discussion was that each was connected with a phase of denudation more or less intense. When, to the results of these cycles of erosion in Palæozoic times, was added the subsequent chapter of events, which have already been briefly discussed for the Carboniferous, it was submitted by the speaker that strata which have undergone such prolonged and repeated cycles of denudation would hardly have preserved large deposits of a volatile material like oil, supposing that they had been originally petroliferous.

Of course, some of the heavier material might have remained in Carboniferous or older rocks, or special structural peculiarities might have served to preserve small bodies of lighter material in strictly localised reservoirs, such as perhaps the instance at Kelham. But the prospector was looking for something which was in a different category; he would be satisfied with nothing less than a commercial oilfield. In the opinion of the speaker there was very little likelihood of this expectation being realised, having regard to the geological history of Britain and the structures which were known or could be surmised. Geologists in this country had been very unwillingly forced to the conclusion that England is not richly endowed with reservoirs of crude petroleum.

If disappointment followed the expectations which have been aroused, the speaker feared that geologists would be called on to share the blame, and it was clearly their duty, at this stage, to state their opinion, however unpopular it might be.

Mr. D. A. Sutherland wished to congratulate Mr. Dalton on his courage. He thought it well that the note of warning which had been uttered should be sent out from the Institution, so that the general public might not be misled by the headlines in the press to which reference had been made. At such a time as this public money should not be wasted. Needless to say, such operations as might be undertaken should be conducted with the greatest care as to the selection of the districts, and should be limited to a definite number and definite expenditure until definite results were obtained. There was no question but that the drill was the only method of finding out whether petroleum existed in payable quantity in Great Britain or not. While he was in favour of settling the doubt by drilling, he hoped money would not be wasted in indiscriminate endeavours where there were no geological indications of sources of supply. Petroleum, like gold, was one of the most widely-distributed substances, but also frequently occurred in traces only.

Perhaps the most important item in the analyses quoted was the bromine absorption. Shale oil contained a high percentage of olefines which would absorb bromine, while natural petroleum contained little or none.

If experimental drilling was to be carried on in Scotland he would like to see the district referred to, and some others tested, as he thought the results might be of importance.

Mr. W. H. Dalton replied to some of the points raised. He could not deal fully with Mr. Cunningham Craig's observations on the Scotch field, because he was unacquainted with it, and had to rely upon the *Survey Memoir*. With regard to the region around Liberton, he understood that it was intensely folded, an overturned syncline faulted against the great Pentland anticlines, which would involve great friction and certainly some crushing.

The bromine-figure given for the Broxburn Sandhole oil was in favour of its being, as he had suggested, the product of a natural distillation, whilst the abundant olefines in the manufactured shale oil attested only the wide difference between nature and art.

Mr. Craig had suggested the existence of oil-bearing anticlinal puckers within the wider synclines. Many good oilfields, in Burma for example, occur in this form, but who could hope to detect such under a cover of 1,000 ft. or more of independent overlying rocks, whilst the 5,000 ft. pierced in Queensland would, in many English districts, pass into metamorphic rocks.

The Millstone Grit showed no trace of oil on its wide outcrop

and mile-thick mass from Derbyshire northward. The series had thinned out to merely 240 ft. at Kelham, and the oil sand was but 16 ft. thick. Such thin bands rarely covered much area. As for the Carboniferous Limestone, all the reported occurrences of oil were mentioned in the paper, and constituted no adequate basis for hope of a paying yield from that series.

He had essayed to arrest the spread of the oil fever by the mild prophylactic of suggestion, but some of the speakers desired drastic surgical operations, which would intensify the evil. Were borings put down every quarter of a mile all over the Kingdom, and carried to the crystalline rocks in every case, there would still be grumblers who would want the intervals reduced to 200 yards.

Interesting, and possibly valuable geological information would be acquired, especially as to water-supply, and in some cases as to coal, but oil, if found at all, would be in mere pockets, of no commercial value. Public money expended in boring would be reprehensible waste. The primary purpose of the paper was to show that there are *no* prospects of petroleum in the British Isles of value commensurate with the cost of search and exploitation.

The President felt that all had listened to the paper and the discussion with the greatest interest; personally, he had listened with instruction to himself. He did not propose to enter into the scientific and speculative investigations which had been made that night, and if he did so, he did not think that his views would be of any value. If, however, he might be permitted to summarise what had been said, or rather to give the impression created in his mind as a commercial man, the conclusion he had arrived at and would like to express was this: that the search for oil in this country would certainly be "wild-catting" of the very worst order, but that the "wild-catting" was justified in every way; that the importance of the matter to this country was so great as to make it perfectly justifiable for the Government to spend a very large sum of money upon it. If he had control of the Government funds, he should think he was justified in spending a million pounds on the search for oil in this country, although "wild-catting" of the worst kind. He would close the proceedings with the request that members would accord to Mr. Dalton a hearty vote of thanks for his very able and interesting paper, and one also to Mr. Holiday for his able reading of that paper.

Mr. H. R. J. Conacher, of the Pumpherston Oil Works, being unable to attend the meeting, wrote as follows:—

I have read your paper with very close interest, and regard it as a

very helpful and opportune contribution to the discussion of a subject of much national importance. I hope it will help public opinion to a more balanced view of the subject in question than that which has obtained so much prominence in some quarters. I am very glad to find that your wide experience of oilfields has led you to the same conclusion as I have reached, especially as your opinion is quite free from any suspicion of bias, such as might be imputed to the views on this subject of anyone connected with the Scottish Oil Industry.

With regard to the occurrences of oil in the Scottish shalefields, I am at one with you in attributing these to the action of igneous intrusion in most cases, although some few are *perhaps* traceable to dynamic heat. You mention the phenomena in the bores in the neighbourhood of Newyearfield, discussed in the *Survey Memoir* by Mr. Carruthers, whose observations are relied upon by Mr. Cunningham Craig in his recent papers; I have gone very carefully into the circumstances connected with this, and do not agree with Mr. Carruthers on the following important points:

(1) The smell of oil is distinct for several hundred feet above the top of the Pumpherston Shales, and the sandstone underlying the Burdiehouse Limestone contains oil and wax, such as are got when shales have been destroyed by igneous rock.

(2) In the shales themselves, and the thick shaly beds overlying them, all plant-remains are graphitised, while globules and patches of *coked* oil are abundant.

It seems clear to me that, although igneous rock has not been detected, there is clear evidence of the action of intense heat long after the accumulation of the rocks, and the small production of petroleum brought up by the underground water has been distilled from the shales, so that presumably some large body of igneous rock exists at no great distance. The fact that the evidences of petroleum and of burning occur in diminishing degree for so great a distance above the Pumpherston Shales disposes of the suggestion of contemporaneous burning advanced by Mr. Carruthers.

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Compiled as adjunct to Mr. E. H. C. Craig's paper, presently following.

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